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From no mobility to future mobility: Where COVID-19 has accelerated change

Compendium 2020/2021

Content

From no mobility to future mobility: Where COVID-19 has accelerated change

Compendium

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From no mobility to future mobility: Where COVID-19 has accelerated change

The COVID-19 pandemic has disrupted mobility, and its effects will linger well into next year. How will changing consumer preferences, technologies, and regulations shape the market in 2021?

December 2020
Center for Future Mobility Compendium 2020–21

COVID-19 swept across the globe in a matter of months, jeopardizing lives, upending businesses, and setting off a worldwide economic slump. Consumers are intensely focused on health and have altered many long-standing habits and preferences to avoid infection. Within the mobility sector, this means that many passengers favor transport modes perceived as safer and more hygienic. Suddenly, private cars are in and shared rides seem to be out. Working from home is on the rise, again with the goal of preserving safety, while business travel and all the mobility services attached to it—flying, taxis, e-hailing—are in low demand. The best-laid plans of mobility players appear to be in tatters. It may seem that the acceleration of future mobility has come to a halt, but this first impression overlooks recent developments that will have a tremendous impact on mobility's future.

Consider some recent developments: cities have redefined car lanes to create more space for bikes and scooters as people began to avoid public transportation. Similarly, government incentives to help the automotive industry have encouraged the use of carbon-neutral solutions and stimulated the development of electric vehicles (EVs). In another shift arising from the pandemic, consumers are increasingly turning to digital channels—from convenient food deliveries to streaming services—and they now expect mobility players to expand their online offerings.

Such fundamental changes, along with other recent developments, are prompting mobility leaders to reimagine the future of mobility. They had already been adjusting their strategies to the emergence of ACES—autonomous driving, connected cars, electrified vehicles, and shared mobility—and now they are going even further to account for the pandemic's impact on consumer behavior, policy making, and regional economies. The following shifts are likely to persist long after COVID-19 is controlled and thus deserve particular attention:

— *Customer preferences.* In addition to safety, consumers are becoming more focused on digital channels and sustainability issues. Access to micromobility options—lightweight vehicles such as bicycles, e-scooters, and mopeds—will be important, as will safety and health issues.

— *Technology.* The pace of change will continue to accelerate in all areas, including connectivity, autonomous driving, and urban transport.

In addition to safety, consumers are becoming more focused on digital channels and sustainability issues. Access to micromobility options—lightweight vehicles such as bicycles, e-scooters, and mopeds—will be important.

— *Regulations.* We expect regulators to become even more active within the mobility sphere. Many, for instance, are tightening CO_2 regulations for vehicles as they attempt to reduce climate change.

Exhibit 1 summarizes some of the most important shifts in these areas.

The articles in our compendium explore the major developments within mobility in 2020 and also look ahead to 2021, as approved vaccines will, it is to be hoped, limit the spread of COVID-19 and usher in the next normal. Here are a few of the topics we will explore.

Consumer preferences

Many car dealerships closed in 2020, and car buying plummeted, especially early in the year. In February, sales were down 71 percent in China; in April, they decreased by 80 percent in Europe and 47 percent in the United States. Likewise, mobility behavior changed drastically during the pandemic, as many commuters worked from home and others avoided public transportation because of health concerns. While consumers have traditionally focused on time to destination, cost, and convenience when selecting a transport mode, they now cite the ability to reduce the risk of infection as their major consideration (Exhibit 2).

In a related trend, transport modes that are considered safe have become more popular. With consumers focused on avoiding infection, mobility service providers quickly implemented a range of safety improvements (Exhibit 3). These changes will persist, and providers may soon add other safety measures that span the entire customer journey. Changing consumer preferences may give private-car use the greatest boost, but micromobility options and walking/biking are also expected to gain ground.

Consumer preferences related to ACES

The articles in our compendium also examine how customers perceive ACES developments. In a recent survey, which examined consumer mobility preferences worldwide, we found that customers believe traditional automakers are well qualified

Exhibit 1

Recent changes in mobility regulations will have lasting repercussions.

Customer preferences

- New emphasis on safety and health: reducing risk of infection is now the top consideration when choosing transport; recent hygiene improvements in public transit and shared mobility are viewed as effective
- Micromobility: use of bicycles is expected to increase 5 percentage points, and shared micromobility is expected to increase 3 percentage points after the pandemic
- Digital sales experience: more than 80 percent of car buyers use online sources, and only a third of the 18–34-year-old customers would prefer to buy their next vehicle at the dealership rather than online

Technology

- Renewed focus on partnerships and collaborations: the industry will continue to consolidate: more than 420 partnerships in ACES have been concluded in 2020 compared with 110 in 2015 (major OEMs only)
- Investments in innovation: investments in mobility start-ups have stabilized, with about $45 billion invested in 2020
- Emerging technologies: urban-air mobility, 5G, and quantum computing could transform mobility; the software and electronics market is expected to double in size by 2030

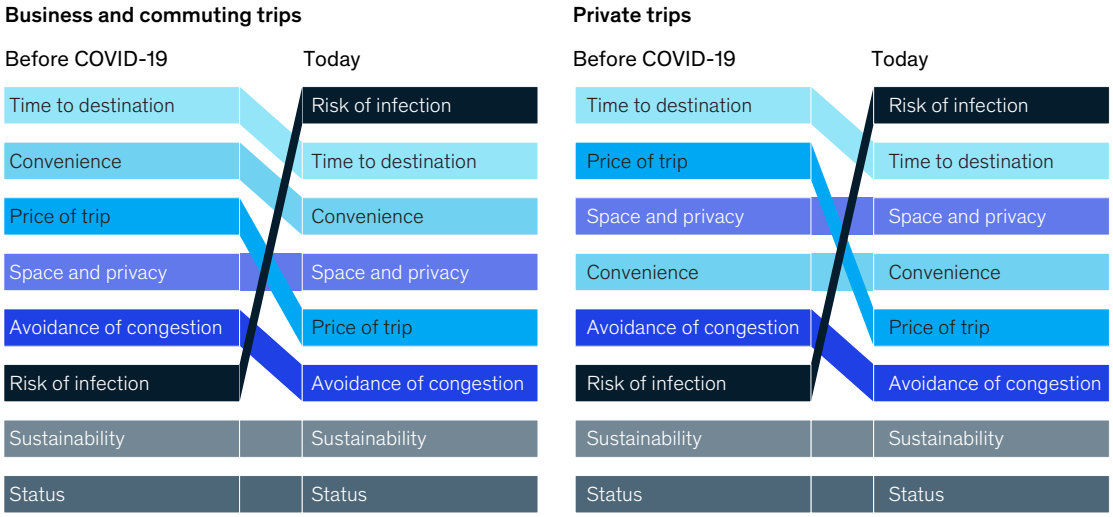
Regulation

- City redesign for alternative transport modes: during the pandemic, many cities announced new mobility regulations, such as the creation of bike lanes; more than 150 cities globally have restricted access for private vehicles
- Electric-vehicle surge and development of the electric-grid infrastructure: the European Union has proposed raising CO_2 targets from the current 40 percent to 55 percent in 2030; California will ban the sale of new cars with internal combustion engines

Exhibit 2

Reducing the risk of infection has become the primary reason for the choice of a mode of transportation.

Key reasons to choose a mode of transportation,[1] rank

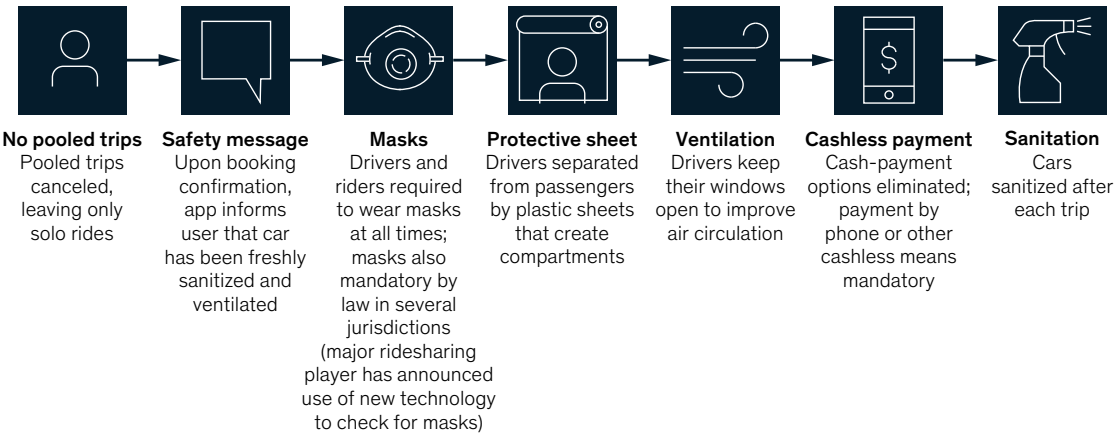


[1]Question: What were/are your key reasons to choose a mode of transportation? Aggregated results from China, France, Germany, Italy, Japan, UK, and US. Reasons ranked by number of respondents.
Source: McKinsey Center for Future Mobility

Exhibit 3

Mobility players have implemented measures to improve hygiene across the entire customer journey.

Examples of safety measures implemented in customer journey



to drive ACES innovation. That finding marks a big departure from previous surveys, in which consumers stated that established OEMs lagged behind their Asian counterparts and start-ups in pursuing ACES trends.

Some of the greatest changes in consumer preferences relate to EVs. Insights from our EV consumer survey show that consideration of EVs has increased by an average of about 21 percent over the last three years, partly because buyers are now more aware of their benefits. Still, consumers have significant concerns about EVs, such as those regarding battery/charging, driving range, and higher costs compared with ICE (internal combustion engine) vehicles. These issues may explain why relatively few consumers move from EV consideration to purchase.

EV sales are not destined to remain low, however. As automakers recognize the growing interest in EVs, many have begun revising their go-to-market (GTM) models for this segment. A seven-step approach may help to increase their sales significantly (Exhibit 4).

The growing importance of online channels

In addition to exploring new products and mobility options, consumers are interested in new services. This shift is clearly apparent in automotive retailing, where a future beyond bricks and mortar is emerging. Although consumers still rank dealership visits as the top factor influencing purchase decisions, digital channels are becoming more important. In a recent survey, more than 80 percent of respondents used online channels during the purchase-consideration period, and more than 60 percent said it would be appealing or very appealing to have digital channels for booking, paying, and reviewing additional services (Exhibit 5).

New attitudes about auto financing and vehicle ownership

Consumers are now open to financing their vehicles through digital channels: a survey of auto-financing executives showed that respondents expect online business-to-consumer sales for auto loans and leasing to reach a market share of approximately 20 to 25 percent by 2025 (Exhibit 6).

The same survey suggested that more consumers may be open to forgoing car ownership in favor of vehicle-subscription services. While such subscriptions are still niche products, they show strong promise. Demand may be particularly strong for fully flexible products, such as leasing models with nonbinding durations.

Technology

Although many mobility players focused on responding to COVID-19 in 2020, they continued

Exhibit 4

Seven innovations will shape the electric-vehicle go-to-market model.

Exhibit 5

Digital channels are becoming more important in the automotive-purchase experience.

Offline touch points still represent key parts of the car-buying journey ...

No. 1
Ranking of dealership visits as a factor influencing purchasing decisions

~70%
Car buyers who consider the dealership a major touch point for physically experiencing the car

2–3
Dealership visits per customer prior to purchase is still the norm

... while online touch points are increasingly shaping customer decisions and experiences

>20%
Use of online sources compared with offline sources during purchase-consideration period

>80%
Respondents who use online sources during the purchase-consideration period

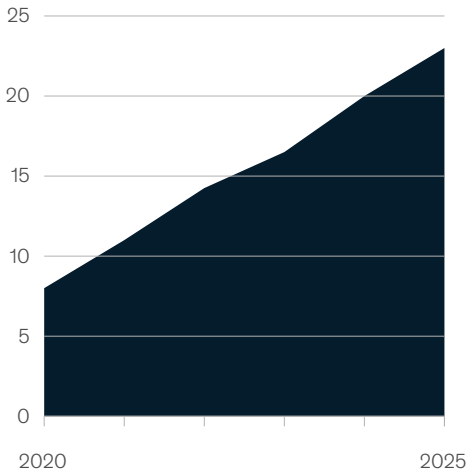
>60%
Buyers who perceive booking, paying, and reviewing additional services online as (very) appealing

Source: McKinsey Automotive Retail Consumer Survey (China, Germany, United States)

Exhibit 6

Auto-financing executives expect online business-to-consumer sales for auto loans and leasing to reach a market share of around 20 to 25 percent by 2025.

Expected share of online B2C sales for auto loans and leasing until 2025, % estimated by respondents



~20%–25%
of sales through direct online channel expected in 2025

Source: McKinsey European Auto Finance Survey 2020

to invest in ACES. Funding such innovations has always been challenging given the high costs, and the pandemic has exacerbated this issue because traditional OEMs have undertaken cash-preserving measures and cost-cutting initiatives that leave little room for technology investments.

OEMs and suppliers may mitigate some funding issues by undertaking partnerships with other companies. Even before COVID-19 hit, many companies were investing in these ventures, with the number of ACES partnerships increasing 40-fold over the past decade (Exhibit 7). With COVID-19 putting budgets under pressure at OEMs and suppliers, these partnerships will become even more essential.

Electric vehicles

Technology advancements are arguably most apparent within electric mobility. As an article in our compendium explains, the automotive industry will introduce about 600 new battery-electric vehicles (BEVs) and plugin-hybrid EVs through 2025, increasing customer choice significantly. Over that same time frame, OEMs will devote more than $120 billion in capital expenditures to BEVs—about 25 to 30 percent of the total (Exhibit 8).

Europe and China are currently in the lead with EVs, as measured by our yearly McKinsey Electric Vehicle Index. The European market grew 44 percent between 2018 and 2019, even as growth slowed in many other countries. China saw slower growth than Europe during this period, but it remains the largest EV market. There are many established Chinese players and new entrants, all of which compete fiercely at the local and global levels. Our benchmark of ten leading Chinese BEV models shows the dominance of local companies. These players account for 85 percent of BEV sales within China and 57 percent globally.

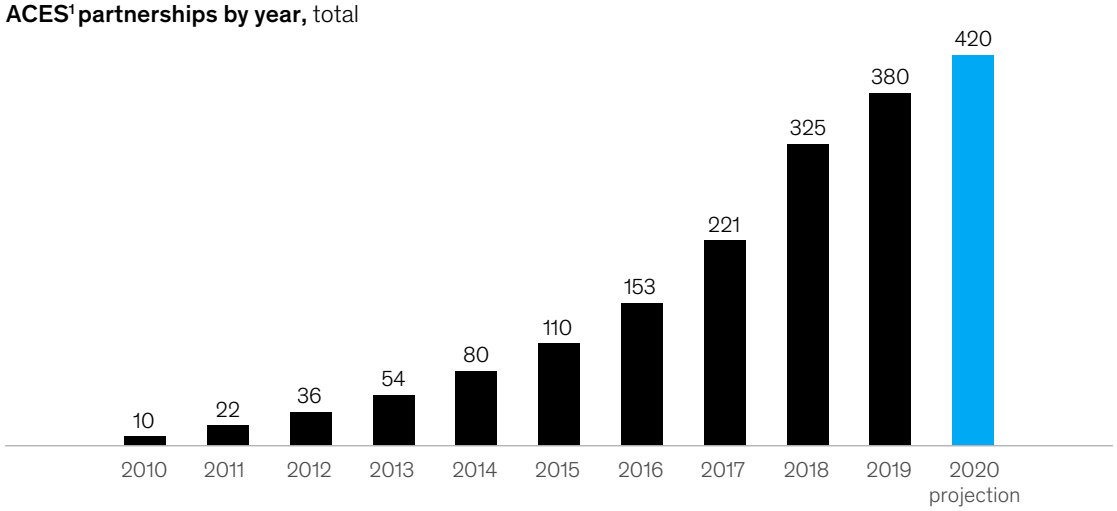
Automotive electronics and software

The role of automotive electronics and software continues to become more important, with both markets expected to see strong growth (Exhibit 9). Components that will be in strong demand include electronic control units (ECUs) and domain control units, which will account for an estimated $156 billion in annual sales in 2030. Software—functions, operating systems, middleware—will account for $50 billion in annual sales.

Exhibit 7

The past decade has seen a 40-fold increase in the number of ACES partnerships, with a heavy focus on electrification and shared mobility.

ACES[1] partnerships by year, total

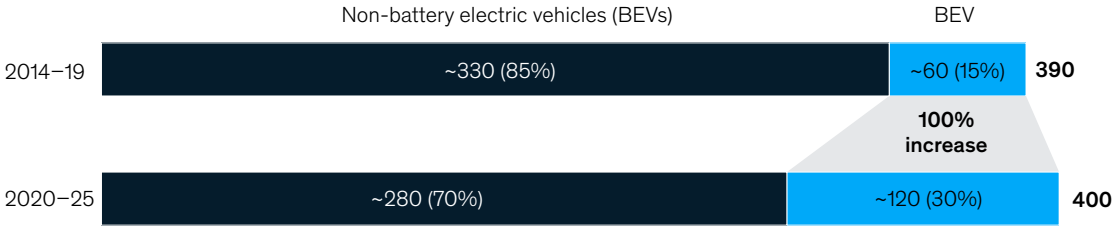


[1]Autonomous technologies, connectivity, electrification, and shared mobility.
Source: McKinsey Moves Database; press search

Exhibit 8

Capital expenditures for BEVs will probably double over the next five years, while investments in other vehicles decline.

Cumulative global model-related capital expenditures (capex), $ billion



600 EV models
will be launched in the next 5 years, and more than 450 will be BEVs

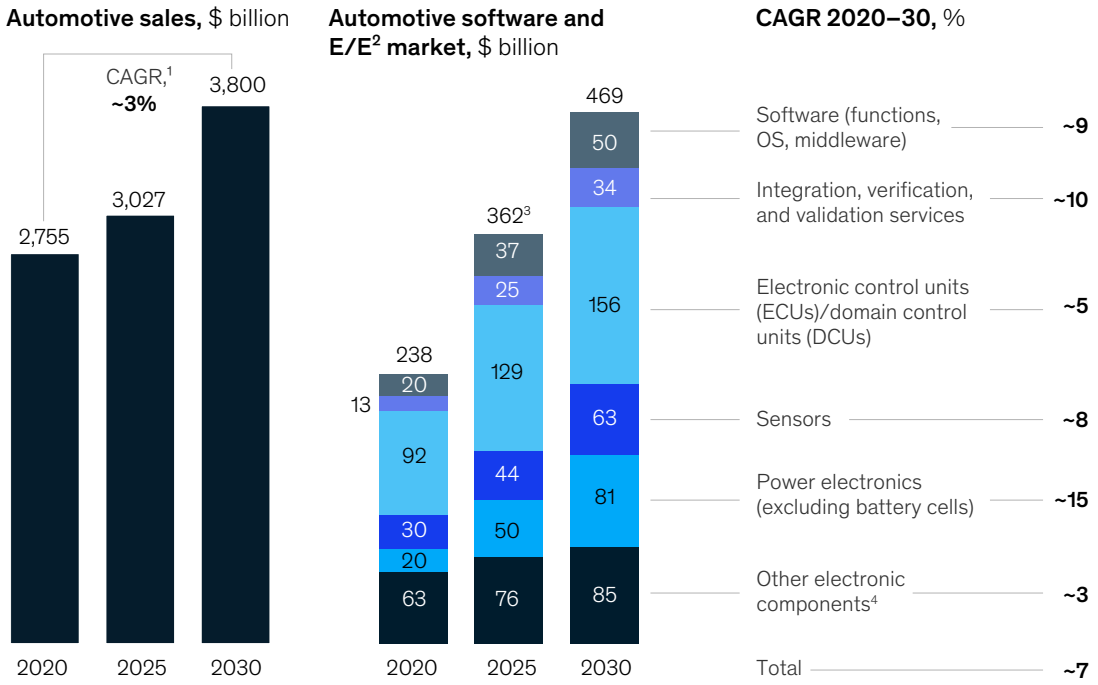
~$120 billion
of global BEV-related capex through 2025

25–30%
of OEM capex will be BEV related

Questions: How has the coronavirus (COVID-19) situation affected your company's production (operation) capacity? How has the coronavirus (COVID-19) situation affected demand for your company's products/services?
Source: McKinsey COVID-19 B2B Decision-Maker Pulse #2, April 20–27, 2020 (n = 607)

Exhibit 9

The automotive electronic and software market will see strong growth through 2030, driven by power electronics, software, ECUs, and DCUs.



[1]Compound annual growth rate.
[2]Electrical and electronic components.
[3]Figures may not sum because of rounding.
[4]For example, harnesses, controls, switches, displays.
Source: Revenue forecasts based on vehicle volumes from IHS Markit (Automotive), Light Vehicle Production Forecast, Oct 2018, pull completed on Nov 6, 2018; McKinsey analysis

Automotive cybersecurity

At many OEMs, cybersecurity has become a top concern. Currently, only narrow standards and guidelines exist for specific technical procedures for securing hardware and software in vehicles, such as standards for hardware encryption or secure communication among ECUs. That will soon change, however. The World Forum for Harmonization of Vehicle Regulations (WP.29), under the UN Economic Commission for Europe, is planning to release new regulations on cybersecurity and over-the-air software updates.

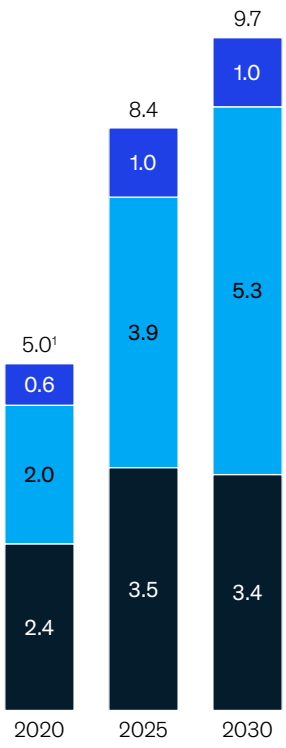
The cybersecurity market is expected to have a compound annual growth rate of 7 percent through 2030, when it will reach $9.7 billion in value (Exhibit 10).

Other technology developments

Many other technology developments are altering the mobility landscape, and innovation will continue to have a profound impact in 2021. Recent advances and potential future developments that our compendium explores include the following:

Exhibit 10

The cybersecurity market will grow significantly for automotive in coming years.



Submarket	Compound annual growth rate, 2020–30, %	
Total	7	
Cybersecurity hardware components	6	Dedicated security components for encryption and key storage (eHSM and TPM)
Cybersecurity-related software-development efforts	10	Implementation of cybersecurity components (eg, encryption functionality) and requirements in functional domains Integration and testing of cybersecurity components and additional effort resulting from cybersecurity requirements in functional domains
Cybersecurity processes and solutions	4	Efforts to implement new regulatory requirements Software traceability (inventory and compatibility management, and impact assessment) Risk management and incident response Vehicle monitoring using security operations centers

[1]Figures may not sum because of rounding.
Source: Analysis based on data from Ondrej Burkacky, Johannes Deichmann, and Jan Paul Stein, *Automotive software and electronics 2030: Mapping the sector's future landscape*, July 2019, McKinsey.com

— With software and high tech becoming more important to vehicles, automakers are increasingly looking for new pools of talent and an innovative R&D model.

— 5G technology, with its superior speed, latency, reliability, and power consumption for handsets and Internet of Things (IoT) devices, has recently become mainstream in many sectors, and there are interesting use cases related to mobility.

— Quantum computing could assist with many steps across the automotive value chain as suppliers, OEMs, dealerships, and others take advantage of its power.

— Urban air mobility is becoming more cost-competitive and could offer new mobility options, provided that sufficient pilots are available.

Regulation

The automotive and mobility industries have always been tightly regulated, but governments around the globe are now playing an ever bigger role by instituting travel restrictions and other guidelines to limit the spread of COVID-19. Even after the pandemic abates, we expect that policy makers will increasingly shape mobility's future through new guidelines and regulations.

New guidelines to limit emissions

To encourage car sales and stimulate the economy, some governments have created policies favoring low-emission vehicles and alternative forms of transportation. The new regulations can vary greatly by region, however. In Germany, for example, purchase-price subsidies for new EVs can amount to more than $10,000 per vehicle. In China, the purchase-price subsidy currently ranges from 16,200 to 22,500 renminbi (approximately $2,350 to $3,265) per car, depending on its range.

The regulatory variations, combined with macroeconomic changes, infrastructure, and other factors, will influence how quickly the EV market recovers in different countries (Exhibit 11). The EV market is much more likely to see a quick recovery and strong growth in China and Europe than in the United States, where the government is not providing EV subsidies. Over the long term, EV market share is also more likely to increase in China and Europe.

In addition to EV subsidies, some governments provide financial assistance to encourage the use of low-carbon transportation alternatives. The Italian government offers its citizens a €500 bonus for buying a bike, and the policy has been so successful that many bicycle shops are out of stock.

Impact of regulations on infrastructure

Government planners are constantly making mobility decisions, since they must design car lanes, pedestrian walkways, EV-charging infrastructure, and much more. Since the pandemic, city leaders have been especially active in making infrastructure changes that affect mobility. Consider a few recent examples:

— Milan announced it will transform 35 km (about 22 miles) of streets previously used by cars to walking and cycling lanes.

— Paris will devote 50 km (30 miles) of lanes usually reserved for cars to bicycles; it also plans to invest $325 million to update its bicycle network.

— Seattle permanently closed 30 km (20 miles) of streets to most vehicles at the end of May 2020, providing more space for people to walk and bike after the lockdown.

— Berlin repurposed some residential streets as "play streets" on Sundays during the lockdown and is also discussing the possibility of extending the program to other days of the week.

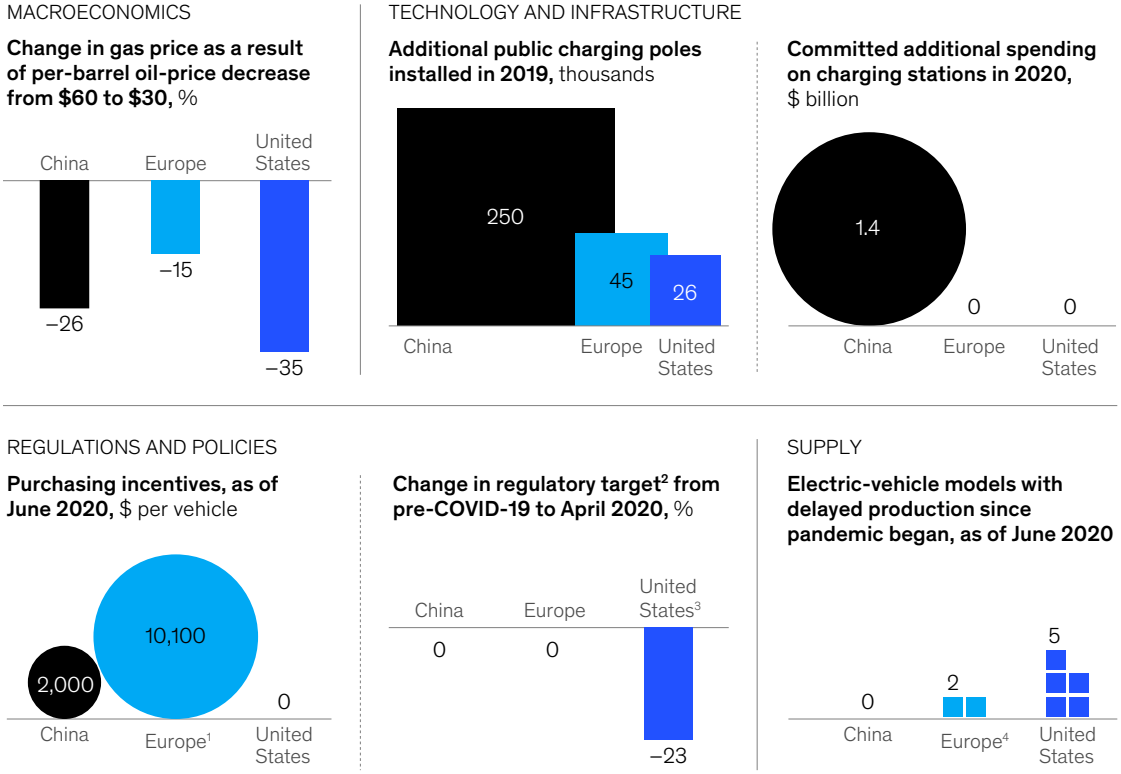
The outlook for 2021 and beyond

Certainly, no one could have imagined how the world would change in 2020. Next year will also bring much uncertainty, but one thing is definite: mobility will continue to evolve in exciting ways. Here are the major developments we expect:

Exhibit 11

Multiple forces will shape the future electric-vehicle market, but their impact will vary by region.

Key drivers by selected focus areas



[1]Total purchasing incentives in Germany; similar incentives have been enacted or are under consideration in other European countries.
[2]Target of grams of CO_2/kilometer.
[3]2025 US federal-fleet-consumption target.
[4]Both model launches by US-based OEMs.
Source: *Autozeitung;* Electrek; electrive.com; European Alternative Fuels Observatory; *Handelsblatt*; NBC Universal; Renewable Energy World; Statista; Vox Media; McKinsey analysis

Expanded consumer preferences and a greater focus on sustainability

When the COVID-19 pandemic is controlled—it's to be hoped at some point in 2021—consumers will be more willing to use public transport and other forms of shared mobility. We expect that sustainability will continue to be an important consideration, with more consumers opting for electric and micromobility solutions, especially in cities. Car sales may continue to decline from their 2019 peak, as more consumers consider alternatives to car ownership.

Continued technology disruptions and widely available innovations

Automotive technology will continue to evolve in 2021, and consumers will have greater access to innovations. For instance, 60 percent of premium OEMs plan to have some form of level 4 automation in their vehicles by 2025. Vehicle electrification will also continue, and innovations could drive EV costs down even further. (The total cost of ownership for BEVs has already reached parity with ICE vehicles in the C-segment.) For technology overall, we expect that software will increasingly become the key differentiator for vehicles.

Regulation will continue to enable the mobility revolution

Continuing the trend seen in 2020, many regulators will focus on environmental issues when enacting mobility guidelines. For instance, European officials are planning to create more stringent carbon-reduction targets to meet the Paris Agreement on climate change. Many governments are also creating new incentives to boost the sales of carbon-free means of transport, and others are issuing guidelines with similar goals. Already, more than 150 cities in Europe restrict access to their centers to reduce pollution and carbon emissions.

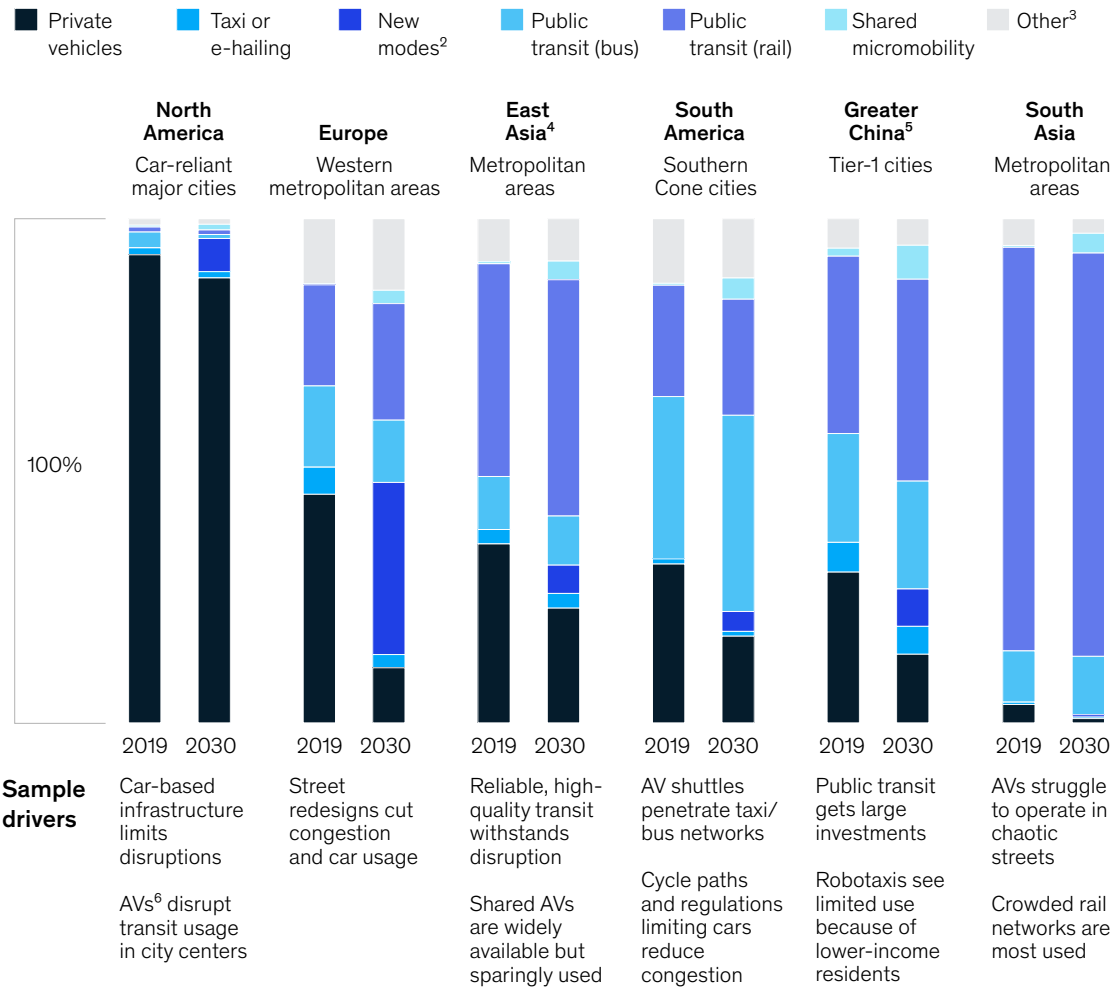
Long-term mobility shifts

Over the next decade, the changes in consumer preferences, technology, and regulations will contribute to major mobility shifts (Exhibit 12).

Exhibit 12

Comparing large global cities highlights significant differences in expected regional mode-share shifts through 2030.

Passenger miles traveled, by city archetype,[1] %



[1]Policy-guided shift to pooled autonomous-vehicle and transit scenario. [2]New modes include roboshuttles, as well as pooled and unpooled robotaxis. [3]"Other" includes walking, biking, private micromobility, 2- and 3-wheelers. [4]Utilizes Japan city archetype for Tokyo. [5]Greater China encompasses mainland China, Hong Kong, Macau, and Taiwan. [6]Autonomous vehicles.
Source: McKinsey Center for Future Mobility

Regional variations will continue to be apparent because of differences in government responses, the intensity of the pandemic, and other factors. For instance, private-car use may drastically decrease in some major European cities. In North America, by contrast, this form of transport will see little change because there are limited incentives to change mobility behavior. Likewise, consumers in greater China may increasingly rely on public transit and rail, but major cities in South Asia will see little change in this area.

Implications for mobility players

The novel coronavirus has forced many businesses, including those in the mobility sector, to cease or slow down operations. It has also accelerated many existing mobility trends, including those related to customer preferences and regulation. As our compendium shows, all mobility players, including OEMs, new entrants, investors, and regulators, must quickly adjust their strategies to navigate the current crisis and prepare for the next normal.

For automotive OEMs and suppliers, surviving and emerging stronger at the far end of this crisis will require thinking beyond the next fiscal quarter. Success in the long run will require a journey across five stages: resolve, resilience, return, reimagination, and reform.

Despite the pandemic, many companies have continued to invest in disruptive mobility technologies, including autonomous technology, connectivity, EVs, and other areas. These businesses have the support of capital markets, and many special-purpose acquisition companies have recently made some successful deals. In 2021, disruptors will exert their presence more strongly. While they may compete with traditional companies in some areas, they will cooperate with them in others.

Regulators will continue to play a major role in helping the mobility sector recover from the pandemic. Many mobility solutions will have an intense local focus and take into account regional variations related to the pandemic, transportation preferences, and city layouts. In addition to creating mobility systems that serve the greater good, regulators will help ensure sustainability. Of course, they must continue to consider technological feasibility while trying to satisfy customer preferences.

The authors of this compendium are members of the McKinsey Center for Future Mobility. **Kersten Heineke** is a partner in McKinsey's Frankfurt office, **Philipp Kampshoff** is a partner in the Houston office, **Timo Möller** is a partner in the Cologne office, and **Ting Wu** is a partner in the Shenzhen office.

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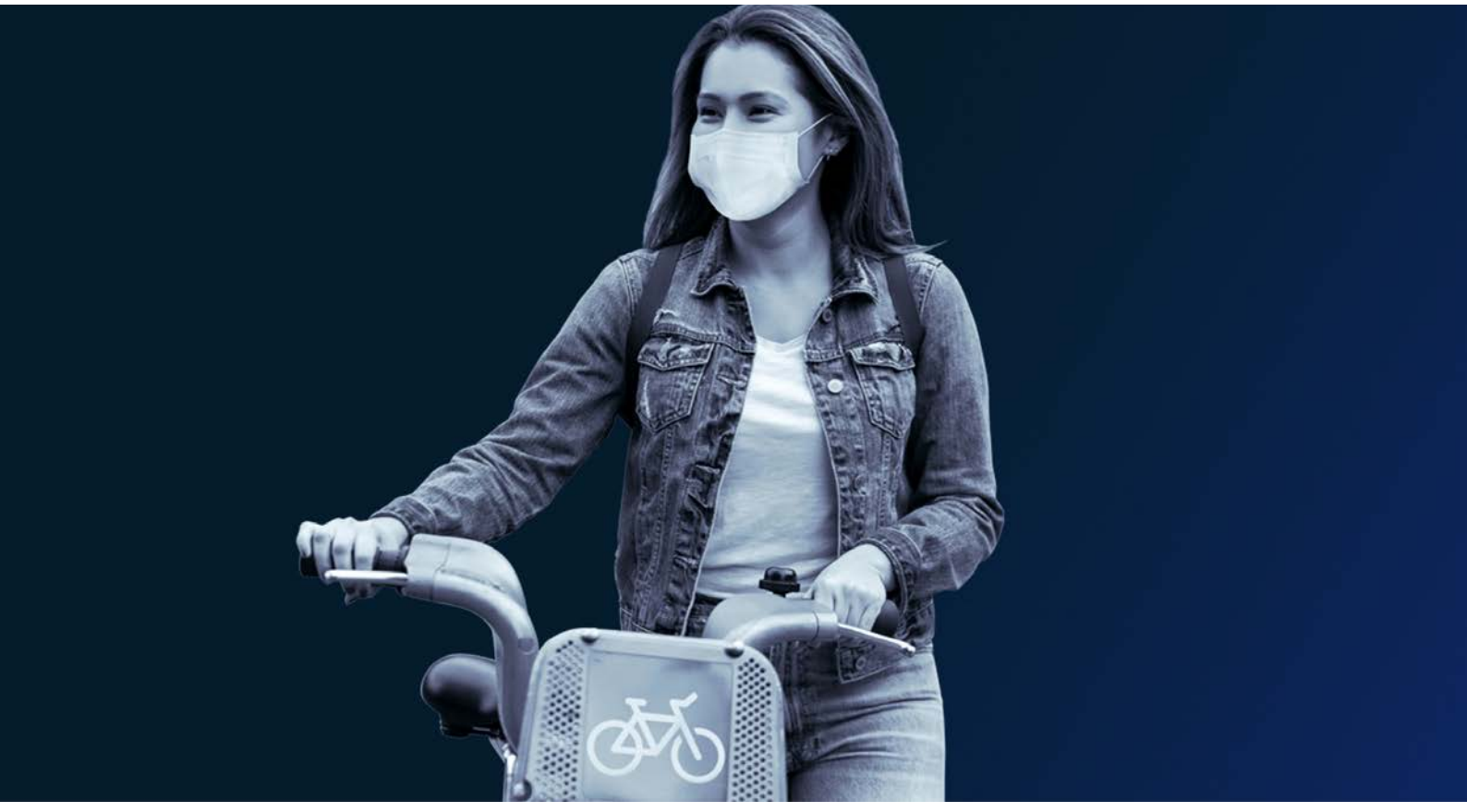
Five COVID-19 aftershocks reshaping mobility's future

The pandemic will change the face of mobility, both now and when the crisis ends.

September 2020

This article is a collaboration by members of the McKinsey Center for Future Mobility, including Martin Hattrup-Silberberg, Saskia Hausler, Kersten Heineke, Nicholas Laverty, Timo Möller, Dennis Schwedhelm, and Ting Wu.



COVID-19 has swept the globe in a matter of months, jeopardizing lives, upending businesses, and setting off a worldwide economic slump. While researchers work to develop a vaccine, with the threat of infection looming, consumers are newly refocused on health. We see this prominently in the mobility sector, with passengers largely favoring modes of transportation perceived as safer and more hygienic, such as private cars over ride sharing. Against a backdrop of mass layoffs, disrupted travel, and public-transit ridership down 70 to 90 percent in the world's major cities, shared mobility—and mobility in general—is struggling. In particular, rumors of the demise of shared mobility are everywhere. Suddenly, private cars are in, shared rides are out, and the best-laid plans of mobility players appear to be in tatters. But are they really?

Developments in personal mobility have coalesced around four disruptions known as ACES: autonomous driving, connected cars, electrified vehicles, and shared mobility. However, since the global pandemic has far-reaching implications on consumer behavior, policy making, and regional trends, automotive and mobility players need to look beyond ACES to consider what will likely influence mobility's "next normal."

Understanding COVID-19's lasting impact

Long term, COVID-19 could have a sustained influence on mobility, driving changes in the macroeconomic environment, regulatory trends, technology, and consumer behavior. Because virus-related trends can vary by region, the responses of mobility players and the outcomes themselves will likely differ by location as well. In this article, we describe what the next normal in mobility could look like and highlight the trends that will define the competitive and technological landscape.

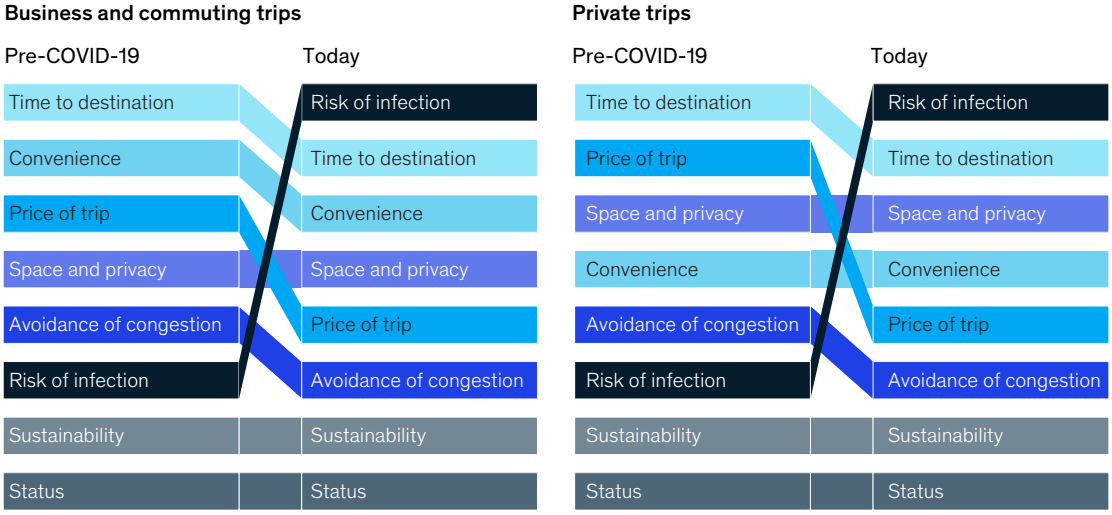
1) More customers emphasize health, safety, and reliability

Cost and convenience have traditionally played key deciding roles when customers choose transport modes. Now reducing the risk of infections is the top reason many travelers make those choices, overtaking even destination time in importance (Exhibit 1). That holds true for both private and business trips. Interestingly, trip price has lost relevance, especially for private travel.

Exhibit 1

Reducing the risk of infection has become the primary reason for the choice of a mode of transportation.

Key reasons to choose a mode of transportation,[1] rank



[1]Question: What were/are your key reasons to choose a mode of transportation? Aggregated results from China, France, Germany, Italy, Japan, UK, and US. Reasons ranked by number of respondents.
Source: McKinsey Center for Future Mobility

With the pandemic, health considerations are more important. Consequently, transport options that guarantee physical distancing will win out over others. In this environment, the use of private cars or biking, walking, and shared micromobility could outpace public transport. Of these, walking and biking are currently the most attractive options.

Based on a recent McKinsey survey of consumer-car-buying behavior during the pandemic, nearly 70 percent of mobility users in the US, UK, Germany, France, Italy, Japan, and China said they would choose to walk or bike at least weekly even after returning to normal life (up six percentage points from precrisis levels). Likewise, private cars gained one percentage point (from 78 percent precrisis to 79 percent after returning to normal life). And, after intense drops in ridership, public transportation users will likely return to at least weekly usage, at around 40 percent. Moreover, shared micromobility, e-hailing, and carsharing should all be slightly more popular, gaining 1 to 2 percent postcrisis when normal life returns. Hence, the overall desire of customers to "move" remains intact.

What's more, even a sizable increase in the number of people working from home would likely not affect mobility demand in the long term. In Germany, for example, even if the amount of people working from home once a week were to increase two and a half times, our analysis shows that it would only reduce the number of trips taken by 2 percent and the number of kilometers (km) driven by 4 percent.

Bigger changes are likely to occur with long-distance travel between cities. Here we see a substantial shift from the use of planes and trains to cars. About 40 percent of global consumers said they would fly less than before in the next normal, while only 16 percent said they would fly more often. In addition, 32 percent said they would travel by train less often (versus the 18 percent who said they would more often travel by train). By contrast, many more people, 32 percent, said they would travel more frequently by private car, while only 13 percent said they would travel less by car. Because of this, miles traveled on roads might increase substantially, at least in the aftermath of the pandemic. Whether this will have an impact on private-car ownership, affect car rentals, or allow clever shared-ownership models to prosper remains unclear.

2) Policy makers increasingly shape mobility's future

Right now, governments around the globe are severely restricting mobility and overall lifestyle choices. However, in the aftermath of the most critical stage of the pandemic, regulators will likely increase their influence over mobility to either accelerate the disruption or slow it down.

As a means to stimulate the economy, governments could launch policies favoring low-emission vehicles or, by contrast, relax emission standards—as US authorities have done. The Chinese government recently extended its support for new-energy vehicles by exempting them from a 10 percent

Even a sizable increase in the number of people working from home would likely not affect mobility demand in the long term.

purchase tax and maintaining subsidies for Chinese-branded electric vehicles (EVs) until 2022. Likewise, Germany has increased its "environment bonus" for EVs to a maximum of 9,000 euros, paid toward the purchase of a new car. Governments are also expanding their favorable policies to eco-friendly travel beyond cars; for instance, Italy is offering its citizens a bonus of 500 euros for buying a bike, which has led to sold-out bike shops.

In some countries, the state might even extend its influence in the mobility sector by becoming a shareholder in struggling companies. One example of this is in the airline industry.

Cities and government planners are constantly making mobility decisions. They have to design car lanes, pedestrian walkways, EV charging infrastructure, and much more. As consumer behavior has shifted during the course of the pandemic, decision makers have increasingly put cities at the center of the discussions. We expect that the role of cities to foment change will only increase, as people become more interested and invested in the future of mobility.

Some recent examples:

— Milan announced it will transform 35 km (about 22 miles) of streets previously used by cars to walking and cycling lanes after the lockdown.

— Paris will devote 50 km (30 miles) of lanes usually reserved for cars to bicycles; it also plans to invest $325 million to update its bicycle network.

— Brussels has continued transforming 40 km (25 miles) of car lanes into bike paths.

— Seattle permanently closed 30 km (20 miles) of streets to most vehicles at the end of May, providing more space for people to walk and bike after the lockdown.

— Montreal announced the creation of over 320 km (200 miles) of new pedestrian and bike paths across the city.

— Berlin has repurposed some residential streets as "play streets" on Sundays during the lockdown and is also discussing the possibility of extending the program to other days of the week.

Such activities suggest that cities could become decisive actors shaping mobility's future. Authorities could issue "license to operate" permission to mobility providers and take measures to encourage certain modes of transport they consider beneficial. For example, in partnership with a micromobility player, Portland decided to temporarily waive daily fees for e-scooters in exchange for the company's offering of reduced fares. Similarly, the city of Rome has recently partnered with another micromobility player to launch e-scooter services in the city, promoting it as a sustainable and technologically innovative mobility solution.

3) Mobility goes hyperlocal

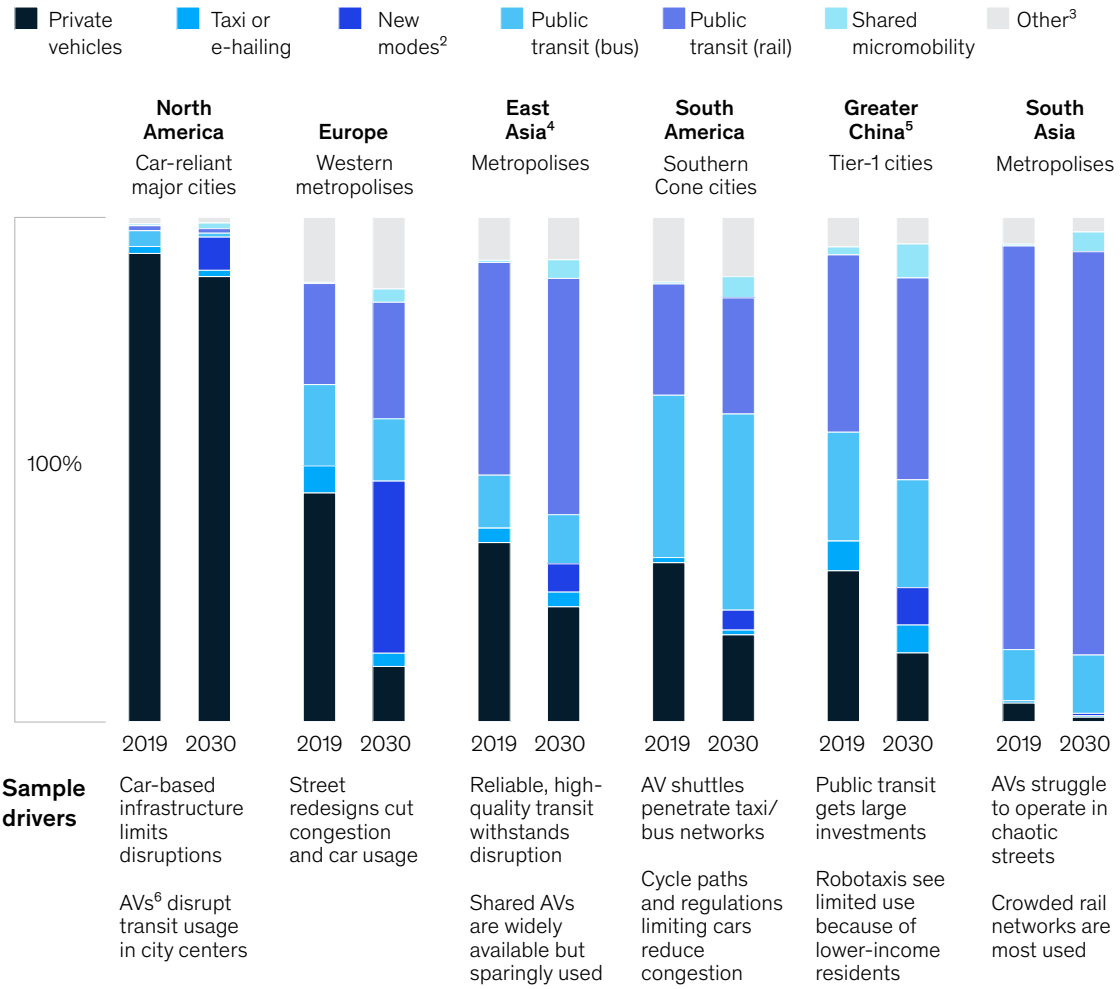
Urban mobility began organizing itself in nonstandardized ways worldwide before the COVID-19 crisis. COVID-19's impact on the world economy has amplified regional differences, with variations on when the crisis unfolded and how health systems have coped. Many of these differences are likely to remain in the months ahead.

Based on our analysis of six major regions, we expect to see dramatic shifts in mobility modes all over the world by 2030 (Exhibit 2). For instance, we forecast a drastic decrease in private-car usage in some major European cities over the next decade, whereas in North America, private-car usage is likely to only decrease slightly. In greater China, we see a larger reliance on public transit and rail, while in major cities of South Asia, particularly those already dependent on public transit to a considerable degree, that is not likely to change significantly by 2030.

Exhibit 2

Comparing large global cities highlights significant differences in expected regional mode-share shifts through 2030.

Passenger miles traveled, by city archetype,[1] %



[1]Policy-guided shift to pooled automated-vehicle and transit scenario. [2]New modes include roboshuttles, as well as pooled and unpooled robotaxis. [3]"Other" includes walking, biking, private micromobility, 2- and 3-wheelers. [4]Utilizes Japan city archetype for Tokyo. [5]Greater China encompasses mainland China, Hong Kong, Macau, and Taiwan. [6]Automated vehicles.
Source: McKinsey Center for Future Mobility

Consequently, depending on the way the pandemic plays out, how stakeholders organize their mobility strategies will vary markedly around the globe—and even from within countries. For example, a city that is an infection hot spot may need to enforce measures strictly limiting mobility, while other cities in the same region or country might operate similarly to precrisis days.

These differences could significantly impact customer demand and available travel options, potentially making mobility truly hyperlocal. Since city policies may vary widely, mobility players will need to tailor their key performance indicators to each city. This could, for example, involve an analysis of emissions regulations, risk of infection, and access to mobility. The pandemic could also become a catalyst for more changes, as cities pursue their own, largely uncoordinated agendas. As a result, mobility players will need to develop a regional and hyperlocal perspective on this emerging mobility patchwork, recalibrating their market radar to anticipate these developments early on.

4) Mobility also scales up

The COVID-19 crisis has exposed the vulnerabilities of certain kinds of companies and business models. We believe such weaknesses will spur industry consolidation. Economies of scale through consolidation might help to create more sustainable business models and, thus, a broader reach. Potential targets include the automotive industry as well as micromobility players, which began consolidating even before the spread of the virus.

One realistic scenario has tech players seizing the moment to secure their stakes in the mobility industry. They possess tremendous cash reserves, and COVID-19 did not hurt them as hard as the traditional economy. A potential secondary effect: cross-industry cooperation on new technologies could intensify as players pool scarce resources.

5) Innovation, refocused

The pandemic has compelled industry players to concentrate on their day-to-day businesses: closing operations, keeping workers safe and healthy, managing supply-chain disruptions, and ramping up production and services once again. However, after this period of crisis management, decision makers will likely want to focus on their innovation portfolios.

The industry's concentration on EVs will likely survive and perhaps even intensify in some geographies. Demand for clean technologies will not disappear. We expect strong EV uptake globally, with sales increasing in China and Europe, given pro-EV regulations expected in the EU. On the other hand, some regions, particularly the US, could also experience slowdowns in the long term, despite having shown strong recovery rates after the pandemic.

Companies may also need to halt or reprioritize other technology investments. For example, we could experience the increased cancellation or postponement of short-term investments in autonomous driving (AD), at least within the "traditional" industry. One tier-1 supplier has already deferred spending on Level 3 AD technology, while two premium OEMs have put their self-driving alliance on hold. Moreover, a North American OEM has delayed launching its commercial self-driving service until 2022 due to the impact of COVID-19 on the business environment and consumer behavior. Such delays could increase the gap between tech players (who lead the AD market and continue to push heavily) and OEMs, perhaps eventually excluding the latter from the autonomous game altogether.

In the midterm, development delays could add months to project timing. After that, the industry will probably see a partial consolidation, triggering an eventual increase in cooperative agreements.

In terms of connectivity, the ongoing consolidation in the startup- and software-technology space offers resourceful companies opportunities to acquire talent, players, or both. This is especially true for OEMs that are more likely to buy capabilities instead of building them in house. While hit hard by the lockdown, shared mobility's future appears intact. Based on M&A activities, many expect the industry's consolidation to continue—especially in micromobility. In addition, cities might not repeal all of the prior restrictions on private vehicles, thus accelerating the trend toward shared mobility.

In addition to the ACES trends, the crisis has hastened the industry's digitization of core processes and sales channels, since e-commerce has become the main option to sell products and services under lockdown. Consequently, companies with digital channels seem likely to emerge from the crisis stronger than their competitors. Consumers now demand new business and sales models that reflect the post-COVID-19 world, such as long-term rentals and subscription services. Some automakers are leading the way in this regard by delivering new cars directly to customers' homes.

Dealing with a topsy-turvy world

COVID-19 has turned mobility upside down. The implications of this crisis are profound and will remain so long after the virus itself recedes. Mobility's next normal will feature changing consumer behaviors, new roles for regulators, hyperlocal mobility, new forms of cooperation, and

COVID-19 has turned mobility upside down. The implications of this crisis are profound and will remain so long after the virus itself recedes.

a changing focus on innovation. Given this uncertain environment, the need for a resilient business model and an agile organization will become even more important.

We believe the impact of the ACES trends will not slow down due to the pandemic. Traditional players need to stay in the game to avoid a diminished role in the ecosystem and missed chances to capture value. At the same time, players face increasing financial pressure and need to focus more attention on cash management. Cross-industry cooperation could be the key to attaining this balance.

Such teamwork could take different forms. For example:

Platform scale. OEMs use the existing platforms of "competitors" for new technologies. One example is the joint EV platform that two global automakers are developing.

R&D collaboration. Some automakers are pursuing joint R&D investments on ACES projects to share investment risk and accelerate development. Two European heavy-truck players used this approach to launch a fuel cell project targeting heavy-duty transport.

Investment consortia. Sharing capital expenditures for large-scale infrastructure projects makes sense. One commercial vehicle player is cooperating with an industry consortium in Austria to set up a system of fully electric last-mile delivery.

Supplier access to new customers and technology. The industry can use acquisitions and cooperation to support access to new customers and technologies, as one Chinese company did when it purchased a German automotive supplier's rotating electrical-products unit.

Supplier consolidation for scale. Automotive suppliers can improve their margins on traditional commodity technologies by pursuing a "last man standing" strategy that can increase their market power. A major North American supplier is attempting this by acquiring its main rival.

The mobility ecosystem is rapidly changing as new agile ways of working and securing talent take hold. The crisis has massively speeded up decision making in traditional companies—a benefit that will likely remain long after the crisis has subsided.

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Coronavirus: Five strategies for industrial and automotive companies

To rebound from the coronavirus pandemic, industrials must undertake a journey that begins with resolve and ends with fundamental reform.

March 2020

by Joe Dertouzos, Heike Freund, Michael Mischkot, Asutosh Padhi, and Andreas Tschiesner

We are still in the early stages of a global health crisis resulting from the coronavirus pandemic. Protecting lives is the first priority, but we must also protect our livelihoods. For automotive and industrial companies, surviving and emerging stronger at the far end of this crisis will require thinking beyond the next fiscal quarter. Success in the long run will require a journey across five stages: Resolve, Resilience, Return, Reimagination, and Reform (exhibit).

Resolve

The first stage, Resolve, involves determining the scale, pace, and depth of action required. To do so, companies in advanced industries must take the following steps:

- establishing a nerve center to steer the organization, serve as the information hub, manage risk and responses, and align all stakeholders
- protecting employees by making their health the paramount concern and adjusting production as needed
- screening and safeguarding the supply chain by understanding risks and taking action to address disruption
- adapting marketing and sales by identifying and mitigating the risks of declining sales while meeting critical customer needs
- maintaining financial health by improving liquidity, reducing costs, and establishing a spend control tower

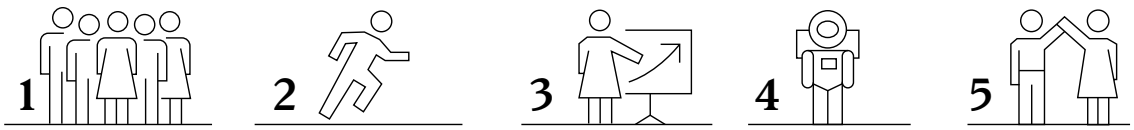
During the Resolve phase, companies must also make difficult choices, such as suspending production facilities, suspending discretionary spending, and furloughing workers. These decisions will require a comprehensive understanding of the situation, including data-driven scenarios for market evolution.

Consider the automotive industry. It is difficult to predict how the pandemic will affect sales in the European Union and the United States, two regions where coronavirus penetration is still emerging. We draw insights about potential developments by looking at the evolution of auto sales in China over

Exhibit

Companies in advanced industries need to think and act across five horizons.

Here's how it applies to automotive and industrial companies



Resolve

Address the immediate challenges that COVID-19 represents to institution's workforce, customers, and business partners

Resilience

Address near-term cash-management challenges and broader resiliency issues during virus-related shutdowns and economic knock-on effects

Return

Create detailed plan to return business to scale quickly, as COVID-19 situation evolves and knock-on effects become clearer

Reimagination

Reimagine the next normal: what a discontinuous shift looks like and implications for how institutions should reinvent

Reform

Be clear about how regulatory and competitive environments in industry may shift

the first quarter, since this country has already "bent the curve" and begun to recover from the coronavirus.

To translate the Chinese case study into scenarios for the European Union and the United States, we examined regional differences in viral spread, economic policy, and auto-specific supply and demand drivers. The latter includes OEM plant shutdowns, government restrictions on travel, consumer confidence, and overall loss of economic wealth. One scenario, which can help automotive companies move forward with greater resolve, is shown below as an example.

Scenario: Virus contained; slow recovery
In a scenario with containment of the coronavirus but a slow recovery, a strong public-health response succeeds in controlling the spread of the coronavirus within two to three months. Policy responses partially offset economic damage, a banking crisis is avoided, and recovery levels are muted.

In the European Union, 2020 real GDP contracts 4.4 percent, much more than the 0.4 percent in China. Temporary automotive plant closures are more extensive than those in China, leading to an estimated 8 percent reduction in production capacity. The strongest constraint, however, relates to consumer demand. Government lockdowns reduce auto sales to 10 percent of the pre-crisis forecast for April. Sales do not recover to 90 percent of the pre-crisis forecast until September, since consumer sentiment is less volatile in the European Union than it is in China. Over the course of 2020, more than five million unit sales, representing 25 to 30 percent of the pre-crisis forecast, are lost.

In the United States, 2020 real GDP contracts 2.4 percent. Similar to the European Union, government lockdowns force April and May auto sales to only 15 to 20 percent of the pre-crisis forecast. Consumer confidence then becomes the limiting factor. Experience from the recession of 2007 to 2009 suggests a slow, U-shaped recovery of consumer confidence. As a result, more than 5 million unit sales are lost in 2020, representing 30 to 35 percent of the pre-crisis forecast.

Globally, the automotive market could go down by as much as 20 to 25 in this scenario. The worldwide numbers are slightly better than those for the European Union and the United States because China is now recovering.

Resilience

As industrials experience virus-related shutdowns and economic pressures, they should move quickly to address near-term cash management challenges and broader resiliency issues.

To understand what makes companies resilient, past downturns provide helpful insight. Some companies also flourish during those hard times—typically those that took significant action at the outset. Our experience shows that resilient companies, defined as those in the top quintile of total revenue share within their sectors, took several key steps:

1. They sustained organic revenue growth throughout the recession and out-performed on earnings and on revenue in recovery.

2. They moved faster and harder on productivity, which preserved growth capacity.

3. They divested 1.5 times more during the downturn and acquired 1.2 times more in the recovery.

4. They maintain clean balance sheets long before a downturn starts.

Compared with non-resilient companies, resilient businesses increased revenues by 30 percent and reduced operating costs three-fold.

The most resilient companies also created end-to-end plans to guide their recovery. They first identified key risks, both internal and external, and then developed a range of scenarios to predict future outcomes. Other important activities included stress-testing the P&L, balance sheet, and cash flows, and then establishing a portfolio of interventions. Resilient companies also set up "cash

war rooms" to improve transparency and implement tighter controls. Finally, the best companies built resiliency dashboards of leading indicators that could be easily monitored and updated.

Return

Restarting production facilities can be more challenging than shutting them down. It requires a thoughtful approach to revive the supply chain, match volume to actual demand, and, most importantly, protect the workforce.

For worker safety, we can again learn from what is already happening in China. Factories there have taken special steps to resume operations. First, they restarted capacity gradually. For example, 20 percent of workers return every two weeks. Second, factories monitor the health of workers continuously. For example, employees get daily body-temperature checks upon entering to screen for potential infection quickly. Third, workspaces are redesigned with modifications that include deactivating elevators, increasing ventilation, and ensuring that workers are well spaced and not stationed to face each other. Lastly, to guard against a single-point failure, workers of the same type are separated into multiple groups.

Given the complexity of global supply chains, ramping up factories in a coordinated way will be mission critical. This will include four important phases:

1. Preparation. Companies reach full transparency about systems, networks, and workforce, including the parts and people available.

2. System filling. Leaders monitor their global supplier networks to ensure readiness.

3. Stabilization. Employees become familiar with the new normal and prepare for volume increase.

4. Ramping up. Companies produce the full product portfolio, matching supply and demand.

Reimagination

The coronavirus pandemic could fundamentally shift how people live, work, and use technology. Advanced industries will likely see a shift in preferences as the expectations of workers and leaders begin to change. The organizations that reinvent themselves will emerge much stronger than those that simply work to reclaim their pre-COVID-19 position.

For industrial companies, this global health crisis may lead to a reimagination of the following:

— *the go-to market approach*, as businesses shift to e-commerce and companies digitize their sales experiences or place greater emphasis on new business models, such as rentals and leasing, to overcome consumer reluctance about purchases that involve a greater commitment

Given the complexity of global supply chains, ramping up factories in a coordinated way will be mission critical.

— *cooperation and alliances*, as "frenemies" work together to promote technology innovation while reducing the funding burden

— *M&A opportunities*, as companies increasingly seek deals when market capitalization approaches historic lows

— *workers' roles*, as businesses further automate warehouses, plants, and facilities

— *geographic footprint*, as global supply chains increase the exposure to health impacts, disruptive trade dynamics, and an uneven global recovery

— *sourcing*, as the incremental costs of redundant sourcing outweigh the hazards of sole sourcing

— *costs*, as a shift from fixed to variable cost enables a lower breakeven volume in times of high volatility

Reform

In addition to dealing with the significant societal changes coming in the next few months, industrial companies may want to consider strategies for addressing some of the persistent issues affecting the sector to avoid the next crisis. For example, they may want to minimize supply-chain risks by increasing local production or dividing production among more sites. Other imperatives include sustainability, workforce flexibility, and adaptability to accommodate changing tariffs. Above all, companies need early-warning systems to detect risks such as the coronavirus and get a head start on preparation.

We see two notable examples of reform emerging in the industrial sector. First, the spread of COVID-19 has already led to greater workforce flexibility, with teams adapting to remote or virtual ways of working. Additionally, companies have added flexible work hours, so that workers can care for children and elder family members during the crisis. In the next normal, we expect to see enterprise-wide flexible employment contracts at scale and more opportunities for remote working, which will allow better leverage of the global talent pool.

In another shift, industrials are likely to make fundamental changes to supply chains to improve their resilience. The current pandemic has revealed the global dependencies of most supply chains, and many industrial companies have shown a lack of contingency planning. With the high level of uncertainty arising from the pandemic, supply-chain leaders are placing more emphasis on forecasting efforts to help them determine global ramp-ups and improve reaction times. Going forward, we expect that local-to-local supply chains will provide more flexibility and that vendors will be more accommodating. We also expect that companies will increasingly adopt digital and analytical tools as they recognize the real value of predictive monitoring and supply/demand matching.

For more than 200 years, the advanced industries sector has underpinned economic and societal progress that has dramatically improved lives. Its technologies have had a flywheel effect, enabling other sectors of the economy and increasing productivity, and its future success will be critical to the world economy and the advance of technology. The new five-step approach can help automotive and industrial companies weather this pandemic and rebound quickly when it abates.

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Designed by Global Editorial Services

The impact of COVID-19 on future mobility solutions

As the global pandemic spreads, mobility players need to prepare for the new world ahead.

May 2020

This article was written collaboratively by members of the McKinsey Center for Future Mobility. The authors include Saskia Hausler, Kersten Heineke, Russell Hensley, Timo Möller, Dennis Schwedhelm, and Pei Shen.

As the COVID-19 crisis rages, public life in many countries is grinding to a halt. The human toll is enormous, with the patient caseload and deaths increasing exponentially worldwide. On the economic side, the coronavirus has forced many businesses to cease or slow down operations.

Automotive OEMs and players within the mobility industry are among the hardest hit. Over the long term, COVID-19 could have a lasting impact on mobility as it drives change in the macroeconomic environment, regulatory trends, technology, and consumer behaviors. The trends may vary by region, however, so responses and outcomes for mobility players will differ by location.

Macrolevel weakness could spur consolidation among mobility players

The current crisis stands to be the most abrupt shock to the global economy in modern times. As with other financial contractions, people will postpone discretionary purchases and increase their savings as they anticipate harder times ahead. According to recent McKinsey research, discretionary consumer spending may decline by 40 to 50 percent, translating into a roughly 10 percent reduction in GDP and numerous second- and third-order effects.

The most immediate and visible effect of COVID-19 in the traditional automotive sector is the standstill of many OEM and supplier factories, which will likely produce 7.5 million fewer vehicles in 2020. At the height of the crisis, over 90 percent of the factories in China, Europe, and North America closed. With the stock market and vehicle sales plummeting, automakers and suppliers have laid off workers or relied on public intervention. Many have secured capital by either applying for government assistance or seeking investor money, while others have extended their credit lines and suspended dividend payments.

Mobility players are also suffering. Public-transit ridership has fallen 70 to 90 percent in major cities across the world, and the operators are burdened with uncertainty and the potential need to implement and control strict hygiene protocols—such as compulsory face masks and health checks for passengers, or restricting the number of riders in trains and stations to comply with space requirements. Ride hailers have also experienced declines of up to 60 to 70 percent, and many micromobility and carpooling players have suspended their services.

Some governments have launched initiatives to support mobility start-ups that were hit hard by the crisis, but low cash reserves and a lack of capital in the market will most likely take their toll on many players. Just recently, a scooter-sharing start-up laid off over 400 employees (30 to 40 percent of its workforce).[1] The potential weakness of some players, combined with the availability of still-cheap money, could trigger a surge in M&A activity in the mid term, leading to a long-predicted industry consolidation.

Regulatory uncertainty could increase

We believe that regulators will react differently across regions. Some might view the crisis as an inflection point to accelerate the transition toward sustainable mobility, while others could loosen regulatory mandates to prop up their ailing automotive industries. In some markets, potential support programs, including cash incentives for trading in old cars, could amplify the industry's focus on sustainability and increase electric-vehicle (EV) sales above projections.[2] In other markets, however, regulators may relax emissions targets to support OEMs.

If physical distancing continues, city leaders might relax regulations for private mobility, at least over the short term, because people feel less vulnerable to infection in individually owned vehicles. Leaders might also revise their regulations to give more space to pedestrians and cyclists. For example, Bogotá, Colombia has added 76 kilometers, or 47 miles, of cycle lanes to encourage physical distancing. Other cities, including New York City,

[1] Julia Arciga, "Over 400 Bird employees were laid off in two-minute Zoom webinar: Report," Daily Beast, April 2, 2020, thedailybeast.com.
[2] Several governments have previously instituted financial incentives for purchasing new cars. For instance, the United States enacted the Car Allowance Rebate System, informally called "cash for clunkers" in 2009 to provide incentives for purchasing new, more fuel-efficient vehicles.

We assume that some of those measures might remain in place after the crisis. If they promote improvements, such as fewer accidents and less pollution, cities may decide to make them permanent.

have closed several streets to traffic. In Oakland, California, an astounding 74 miles of streets—10 percent of the total—have been blocked off so pedestrians and cyclists can remain six feet apart.

We assume that some of those measures might remain in place after the crisis. If they promote improvements, such as fewer accidents and less pollution, cities may decide to make them permanent.

Potential technology setbacks

Over the short to mid-term, the COVID-19 crisis could delay the development of advanced technologies, such as autonomous driving, as OEMs and investors scale back innovation funding to concentrate on day-to-day cash-management issues. For instance, autonomous-vehicle (AV) testing may be suspended. Similarly, investment in micromobility and shared-mobility providers might drop—a trend that would drive market consolidation. Success (and survival) will likely favor larger players with higher cash reserves.

Over the long term, however, AVs, micromobility solutions, and other technologies that support physical distancing could benefit. We believe that customer demand for these solutions could soar once the initial crisis subsides, increasing their attractiveness to investors.

The impact of COVID-19 on EVs will differ across regions. For instance, we expect post-crisis EV sales to rebound strongly in China, keeping investment stable and the projected increase in EV market share on track. We also expect investment to remain on the same trajectory in Europe—even though ramp-up of EVs might be slightly delayed, there could be strong regulatory tailwinds. EV demand might stagnate in the United States, especially if federal regulations about emissions loosen and oil prices remain low. These trends could slightly decrease investment in EVs and market share could fall below the projected levels for the next few years.

Changes in consumer behavior and preferences could shift the modal mix

As the pandemic continues, physical distancing will have a significant impact on mobility behavior and preferences. Many people will switch to a transport mode that reduces the risk of infection, but the exact shifts will largely depend on their pre-COVID-19 habits. People who own a private vehicle will use it increasingly, while those who previously relied on public transport might switch to another mode, such as biking or walking instead. Evidence from Chinese cities confirms that private cars, walking, and biking have gained the most share since the pandemic began, while bus and subway ridership declined.

At this point, we believe many changes in the modal mix are temporary and that shared-mobility solutions, including public transit, will rebound and continue to capture increased market share. Micromobility solutions could also pick up more quickly if strict disinfection protocols are installed. That said, the pandemic could produce some permanent shifts over both the short and long term. For instance, AVs, if approved for on-road use, could see higher-than-expected demand, since they enable physical distancing. And remote work—now common during the pandemic—could become the norm if companies recognize its power. If more people permanently work from home, the reduction in commutes would likely produce a long-term decrease in vehicle miles traveled.

Regional variations in mobility trends

The four trends discussed—macroeconomic developments, regulatory developments, technology, and customer behavior—will evolve in different ways depending on location. We have created scenarios to describe the landscape—both how it might evolve through 2021 and the potential next normal in 2025. Of course, much uncertainty persists and other scenarios could emerge. Here's a summary.

North America

In the United States, future EV-market development depends largely on the regulatory environment and oil prices. The latter, in turn, affect gasoline prices and the total cost of ownership of EVs (Exhibit 1). While EV sales could return to pre-COVID-19 projections in one to two years, the specific timing depends on two factors: if and when oil prices also return to pre-COVID-19 levels and the number of states that adopt California's emission regulations. Although some technological innovation may now face delays, we expect investment to recover.

Exhibit 1

Trends in North America may lead to the continued dominance of road travel and lower electric-vehicle uptake.

Trends in North America by category

	Macroeconomic developments	Consumer behavior	Regulatory developments	Technology readiness
2020–21: crisis years	• Auto factories closed, with some automotive workers losing jobs • Stocks and oil prices plummet	• Shift away from shared mobility and public transit to reduce risk of infection • Uptake in single-occupancy modes • Decrease in vehicle miles traveled due to remote working	• $2 trillion economic-stimulus package may help some OEMs and mobility players • Corporate Average Fuel Economy regulations may be weakened	• Autonomous-vehicle testing temporarily suspended • Demand drop, and shortage of capital puts pressure on start-ups
2025: potential scenario for "next normal"	• Auto industry recovered and plants reopened • Car sales back to precrisis levels	• Road-based mobility dominates; adoption of electric vehicles might level off	• Policies to reduce private-car ownership are dropped • Weakened emission regulation slows down e-mobility transition	• Players double down on investment in autonomous vehicles • Market consolidated; healthy market winners emerge

Europe
While COVID-19 will likely decrease overall car sales in Europe, it might have a limited impact on EV market share and total EV sales (Exhibit 2). It is not likely that governments will weaken strict emission regulations; at most, they might defer or reduce penalty payments. Shared-mobility solutions and EVs might see greater uptake during the crisis and even more afterward. The EV market might see additional tailwinds if the government approves the green-mobility incentives that are currently under discussion.

China
Among countries, China is furthest along in its recovery from COVID-19. In the future, the government might increasingly place limits on private-car ownership in cities, with limited exceptions for EVs (Exhibit 3). The adoption of EVs and shared-mobility solutions could accelerate in urban environments.

Mobility will always be a basic human need. To prepare for the future, mobility-industry players should immediately adjust their strategies to navigate the current crisis and prepare for the next normal:

— As long as the crisis is acute, mobility players must focus on keeping employees and customers safe and establishing dedicated safety protocols. They must also stay connected with their customers, even if operations are temporarily suspended or restricted. For instance, they can keep potential customers informed about safety updates and demonstrate

Exhibit 2

In Europe, shared mobility and electric vehicles may see greater uptake postcrisis.

Trends in Europe by category

	Macroeconomic developments	Consumer behavior	Regulatory developments	Technology readiness
2020–21: crisis years	• Auto factories closed • Stocks plummet	• Shift away from shared mobility and public transit to reduce risk of infection • Remote working and closed borders lead to a standstill	• Strict CO_2 emission regulation • Diesel ban in selected major cities • Potential government incentives to stimulate the purchase of new electric vehicles	• Demand drop, and shortage of capital puts pressure on start-ups • Investments in autonomous-driving technology cut back in favor of short-term cash management
2025: potential scenario for "next normal"	• Automotive industry recovered • Car sales slightly below pre-crisis levels	• Consumers use multiple modes of transport	• Major city centers are car free • Shared and electric mobility increase in urban environments	• Autonomous-driving development slows down and focus is on level-4 highway pilots • Shared micromobility market consolidated, and healthy market winners emerge

Exhibit 3

The Chinese automotive market has begun to recover.

Trends in China by category




	Macroeconomic developments	Consumer behavior	Regulatory developments	Technology readiness
2020–21: crisis years	• Temporary shutdown of auto factories, slight supply restrictions • Slowing global demand leads to a decline in exports	• Shift away from shared mobility and public transit in fear of infection	• Strict emission regulations • Extended state subsidies and tax breaks for electric vehicles	• Demand drop, and shortage of capital puts pressure on start-ups • Crisis catalyzes introduction of autonomous-delivery robots as enabler of physical distancing
2025: potential scenario for "next normal"	• Car sales recovered quickly, but growing at a slower pace because of strict regulation	• Multiple forms of transport used	• Licensed private-vehicle ownership restricted via plate lotteries • Shared and electric mobility dominates urban environments	• Players double-down on autonomous-vehicle technology • Market consolidated; healthy market winners emerge

their commitment to preventing infection. As one example, the electronic displays mounted on ride-share scooters could show when a vehicle was last disinfected.

— Looking ahead, companies can develop a detailed plan for ramping up operations. They may want to begin ramp-up in areas where COVID-19 has had a limited impact, such as cities with lower unemployment rates. Business segments that have been severely affected, such as airport rides, can be ramped up more slowly, since the impact of COVID-19 is likely to linger.

— Companies can also benefit from a thorough portfolio review that helps them focus on profitable operations. They can then decide which technologies deserve increased investment and which should be abandoned, allowing them to emerge from the crisis healthier and stronger. In some cases, companies may want to find partners to reduce the funding burden.

— Finding new opportunities for M&A may also help mobility players thrive.

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Reimagining the auto industry's future: It's now or never

Disruptions in the auto industry will result in billions lost, with recovery years away. Yet companies that reimagine their operations will perform best in the next normal.

October 2020

by Thomas Hofstätter, Melanie Krawina, Bernhard Mühlreiter, Stefan Pöhler, and Andreas Tschiesner

Electric mobility, driverless cars, automated factories, and ridesharing—these are just a few of the major disruptions the auto industry faced even before the COVID-19 crisis. Now with travel deeply curtailed by the pandemic, and in the midst of worldwide factory closures, slumping car sales, and massive layoffs, it's natural to wonder what the "next normal" for the auto sector will look like. Over the past few months, we've seen the first indicators of this automotive future becoming visible, with the biggest industry changes yet to come.

Many of the recent developments raise concern. For instance, the COVID-19 crisis has compelled about 95 percent of all German automotive-related companies to put their workforces on short-term work during the shutdown, a scheme whereby employees are temporarily laid off and receive a substantial amount of their pay through the government. Globally, the repercussions of the COVID-19 crisis are immense and unprecedented. In fact, many auto-retail stores have remained closed for a month or more. We estimate that the top 20 OEMs in the global auto sector will see profits decline by approximately $100 billion in 2020, a roughly six-percentage-point decrease from just two years ago. It might take years to recover from this plunge in profitability.

At the operational level, the pandemic has accelerated developments in the automotive industry that began several years ago. Many of these changes are largely positive, such as the growth of online traffic and the greater willingness of OEMs to cooperate with partners—automotive and otherwise—to address challenges. Others, however, can have negative effects, such as the tendency to focus on core activities, rather than exploring new areas. While OEMs may now be concentrating on the core to keep the lights on, the failure to investigate other opportunities could hurt them long term.

As they navigate this crisis, automotive leaders may gain an advantage by reimagining their organizational structures and operations. Five moves can help them during this process: radically focusing on digital channels, shifting to recurring revenue streams, optimizing asset deployment, embracing zero-based budgeting, and building a resilient supply chain. One guiding principle—the need to establish a strong decision-making cadence—will also help. We believe that the window of opportunity for making these changes will permanently close in a few months—and that means the time to act is now or never.

This article illustrates winning moves and principles for automotive players, often by drawing parallels to players from other industries that have successfully navigated similar "now or never" moments and emerged stronger.

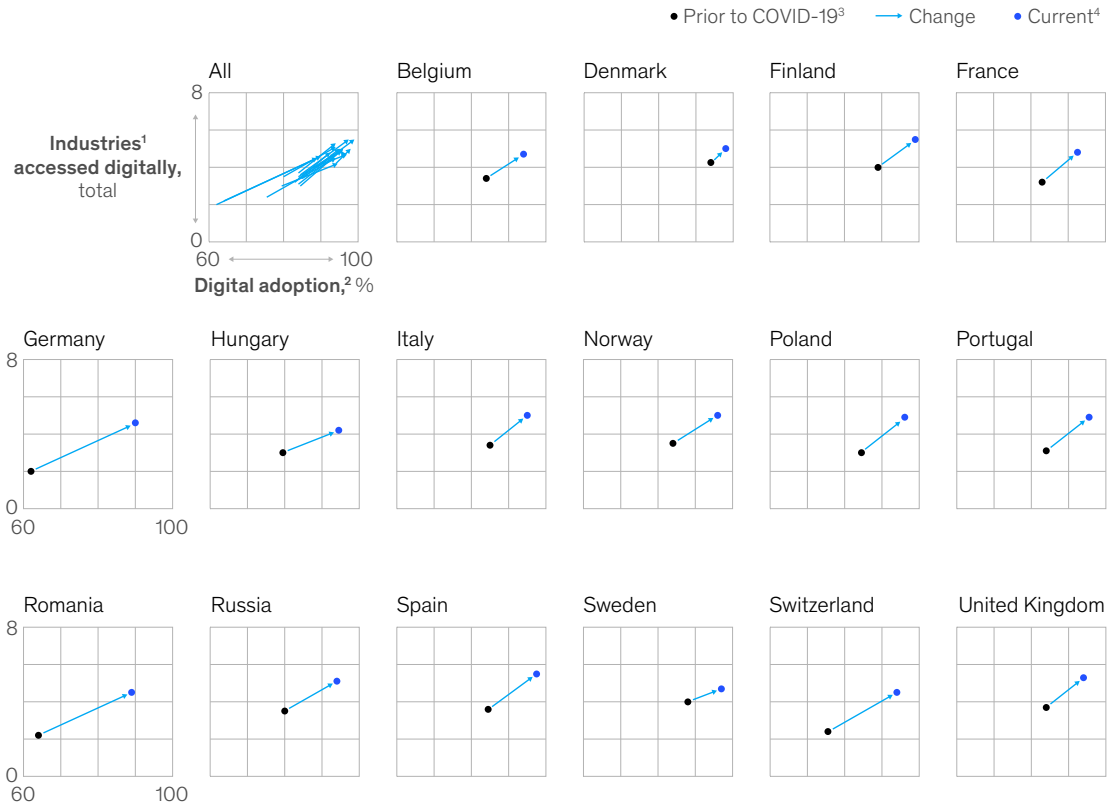
Radically focus online

Right now, more consumers than ever are using online sales channels to engage with businesses in every industry. According to a recent McKinsey digital sentiment analysis, in Europe, the use of digital channels has increased by an average of 13 percentage points (Exhibit 1). Growth in online channels is high for every country surveyed, but the biggest boost has occurred in Germany, which has seen the use of digital channels jump 28 percentage points in response to the COVID-19 crisis. Moreover, 72 percent of first-time users in Germany and 70 percent of regular users are planning to continue engaging online even after the crisis subsides. According to these metrics, having an online presence may be a game changer for businesses.

Exhibit 1

Across Europe, engagement with industries through online channels has increased by an average of 13 percentage points.

More consumers are visiting a growing number of industries online in every country surveyed.



[1]Includes banking, insurance, grocery, entertainment, apparel, social media, travel, telco carriers, utilities, and public sector (for most countries).
[2]Users with at least one digital service in the past 6 months (January–June 2020).
[3]Includes industries visited digitally in 2020 prior to COVID-19.
[4]Includes industries visited digitally during the past 6 months (as of June 2020).
Source: McKinsey & Company COVID-19 Digital Sentiment Insights, June 2020

Automotive players were uncertain about using digital channels before the COVID-19 crisis hit, while companies in other industries aggressively moved ahead. Consequently, the automotive industry now lags other sectors in this area. A 2019 Digital Quotient analysis, which is a McKinsey method for evaluating an organization's overall digital maturity, revealed that the average automotive business has a clear need to digitize, with the industry earning a below-average score compared with other business-to-business (B2B) players.

Industries in general recognize that remote selling models are becoming the next normal, and some players are already preparing for that in reaction to consumer demand. In fact, according to our analysis, positive customer sentiment for digital sales interactions is now about twice that of traditional models. A recent McKinsey study shows that 96 percent of B2B companies have shifted their go-to-market models in response to the COVID-19 crisis, with 64 percent believing the new digital model is just as effective or more so than before.

One US electric-vehicle maker, with established online sales offerings and contactless test-drives, increased its sales in China by over 10 percent early in the COVID-19 crisis.

Likewise, 32 percent of B2B companies say they are very likely to continue to pursue these sales-model changes for more than a year after the crisis subsides, while another 48 percent are somewhat likely to do so.

Digital laggards in other industries have been able to quickly improve their position, and automotive players can emulate them. One clear success story from another industry involves a traditional German catalog and mail-order retail company. After experiencing increasing pressure and significant competition from online businesses and fast-fashion players, the company created a new platform as an online fashion retailer in 2014. Company leaders executed an internal shift in the business and operating models, focusing on personalized offerings, influencer marketing, and mobile-first offers. In addition, the retailer partnered with Germany's largest digital-marketing agency to guarantee successful implementation, since it realized that it might need assistance.

Traditional companies might be surprised to learn that the retailer's app drives 75 percent of its revenues. By betting on mobile, the company outperformed its former competitors and ultimately became Germany's fifth-largest online fashion retailer. Moreover, the company's digital platform has won a Shop Award from *Internet World Business* (a B2B trade journal) for four consecutive years, reflecting its status as one of Germany's best online stores.

A major US newspaper represents another digital success story. In the second quarter of 2020, it added nearly 700,000 digital subscribers, marking the best subscription growth in its history and outpacing the paid online readership of two of its peers combined. For the first time, the newspaper's second quarter revenues from digital products exceeded print revenues. Its long-term goal of attracting ten million subscribers by 2025 will be primarily driven by growing its digital subscriber base and digital content offerings, including podcasts, lifestyle offerings, and multimedia products.

Within the automotive industry, the benefits of adopting a digital strategy surfaced early in the COVID-19 crisis. In February 2020, China experienced an 80 percent decline in overall automotive sales. One US electric-vehicle (EV) maker increased its sales in China by over 10 percent, however. The company had already established online sales offerings, including a clearly structured online shop, contactless test-drives, and car home deliveries, that proved effective during the nationwide shutdown.

Shift to recurring revenue streams

Between February and March 2020, major stock indexes dropped by almost 40 percent, with the drop affecting nearly all industries and markets. Noncyclical stocks reacted with far less volatility, however, and some even grew in value.

In times when cash is scarce and uncertainty about the future abounds, customers often hesitate to make large up-front purchases. Instead, many people prefer short-term, subscription-based offers that do not tie up significant capital. Within mobility, a preference for subscription-based models is often apparent, even during good economic times, especially among younger consumers. Before the COVID-19 crisis, 34 percent of Generation Y consumers expressed a preference for rental and ridesharing products, whereas 6 percent of baby boomers shared the same sentiment. These preferences show how recurring revenue streams could become very important to automotive players. Other factors to consider when mobility players think about increasing recurring revenues include the following:

— *On-demand mobility is on the rise.* The COVID-19 crisis has reinforced the existing trend toward greater flexibility, as customers hesitate to commit to large-scale investments and want flexibility in a fast-changing world. To adapt, many mobility players have already repositioned their offerings to increase customer flexibility. For instance, more rental companies are offering short-term leases as an alternative to car sales, and some OEMs are doing the same.

— *Recurring revenues create robust income streams.* One US EV maker's current market capitalization clearly suggests what will drive the value of mobility players in the future. Traditional vehicle sales accounted for roughly $20 billion of the company's valuation, while software upgrades and over-the-air (OTA) updates contributed more than an estimated $25 billion. Software subscription services, which enable people to pay for programs that unlock features from heated seating to full self-driving capabilities, allow dealerships to develop an ongoing relationship with consumers while offering them additional flexibility and customization. Driven by higher multiples, low incremental costs, and changing customer behaviors, the EV player's offerings are a great match for today's markets.

Optimize asset deployment through strategic partnerships

Investments in autonomous technologies, connectivity, electrification, and shared mobility (ACES) are a challenge for automotive OEMs and suppliers alike. Given the significant resources required and the need to deliver these solutions now, it makes sense for industry players to work together instead of competing alone. After all, the limited resources of traditional OEMs must stretch even further in the COVID-19 crisis as cash-preserving measures and cost-cutting initiatives leave little room for technology investments.

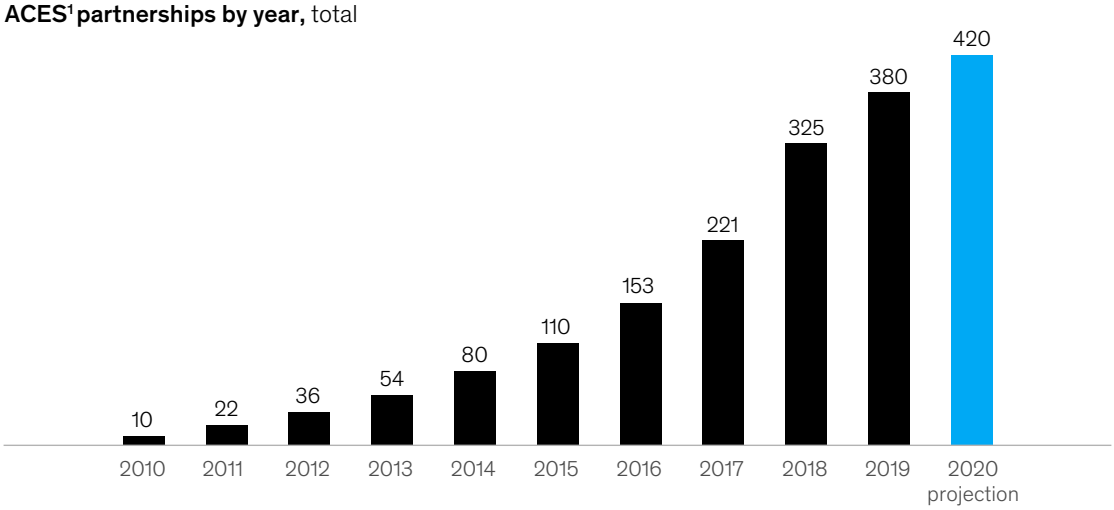
The smartphone industry offers an example of successful cooperation among peers. Beginning in 2019, two tech-giant rivals announced a deal that enabled the music- and TV-streaming services of one player to integrate with the hardware of the other. To do this, one of the companies revisited its former hardware-first approach and cooperated with third parties to boost content and revenue streams from new services. For instance, the player opened its content libraries to a competitor's virtual concierge service and collaborated with yet another company on a contact-tracing tool to combat the global pandemic. Because of these moves, the former tech rivals can now compete more successfully against several new content rivals.

Cooperation in the automotive industry needs to gain the same kind of momentum. Even before the crisis, OEMs and suppliers held long discussions about their focus and technology investments as they attempted to "future proof" their businesses. Auto-industry incumbents face rapidly growing and hugely inventive tech players—from EV makers to autonomous vehicle (AV) innovators—whose leaps and pivots are leaving their slower-moving peers in the digital dust. Their success often results from collaborations with other players, making these arrangements more popular. Over the past decade alone, the number of ACES partnerships have increased by a factor of 40 (Exhibit 2).

Exhibit 2

The past decade has seen a fortyfold increase in the number of ACES partnerships, with a heavy focus on electrification and shared mobility.

ACES[1] partnerships by year, total



[1]Autonomous technologies, connectivity, electrification, and shared mobility.
Source: McKinsey Moves Database; press search

Tech players, already serious competitors before COVID-19, are now placing additional pressure on incumbent OEMs due to their strong financial standing during the global pandemic. For example, one e-commerce player set new revenue records in 2020, with top-line increases of up to 40 percent in the second quarter. It used some of those earnings to buy an AV company for nearly $1.3 billion. Likewise, a videoconferencing player earned a market capitalization greater than those of all the airline companies combined in the first quarter of 2020, showing once again the strong performance of tech players during the crisis—and the potential for fruitful partnerships with cash-strapped OEMs.

The economic outlook for traditional OEMs will likely worsen in the post-COVID-19 world, as cash flows tighten and technology players see continuously strong revenues. Especially in a "winner-takes-all" market, going it alone in terms of investments will be a challenge. If OEMs want to stay ahead of the innovation curve and maintain a future-oriented business, collaborating with former competitors, tech players, and investors will likely become an inescapable fact of life.

Embrace zero-based income statements

The pandemic has devastated auto-industry growth. According to the latest estimates, global car sales will decline between 20 and 30 percent in 2020. Moreover, depending on the region, it may take up to four years to recover to pre-COVID-19 levels.

While plants remain shut down, many people are in short-term jobs or working from home due to pandemic measures. With so many people working remotely, a window of opportunity has appeared to introduce a fresh way to manage a company's profit-and-loss (P&L) statement, for example through including flexible-work locations and, as a result, operating-expenditure savings through physical workplace reductions. Today's higher

degree of uncertainty calls for a shift away from an annual budget toward dynamic resource allocation. Instead of static budgets that restrict their degrees of freedom, automotive players should embrace a zero-based budgeting approach and reconstruct their income statements from scratch.

Under this plan, each business leader defines their "survival minimum" in terms of services performed and budgets needed, rather than basing needs on last year's investments.

A zero-based approach can catalyze long-overdue changes in the automotive industry, including the consolidation of production facilities, the elimination of activities that add little value, and the radical reduction of investments in noncritical new assets. Considering the challenges imposed by the pandemic, the airline industry is currently leading the way in applying agile and zero-based budgeting approaches and reconstructing income statements. Automotive OEMs and suppliers should follow suit.

Build resilience into the supply chain

The early weeks of the COVID-19 pandemic revealed how complex yet fragile global supply chains have become. Already in February, before the outbreak arrived in Europe and the United States, a supply-induced shock caused production interruptions at many tier-one suppliers, as critical parts from China went missing.

The increasing dependence on single-country sources of supply, especially China, has grown more visible due to the crisis. If the links break, the disruptions increase. From 2000 to 2020, mainland China went from producing 5 to 30 percent of the world's manufacturing value added.[1] We have observed that industry leaders now have an increased sense of urgency over supply-chain resilience; several manufacturers in Europe and the United States are considering suitable backups, such as local sourcing or insourcing.

Companies will need to focus on specific areas to make their supply chains more resilient after the pandemic. For instance, they should perform rigorous checks on worker health and product safety, monitoring interactions and flagging concerns. They need to instill confidence among key stakeholders, restarting operations based on data and analytics-driven demand and supply-chain transparency. Overall, organizations should not return to business as usual, but should restart with new, faster processes and tools and scaled, agile practices.

Establish a strong decision-making cadence

Experience suggests that company transformations often fail to gain the necessary traction and rigor for successful execution and implementation. Yet to thrive in the industry's "next normal," excelling in these dimensions is key. Three principles can maximize a company's chance of success.

Industry leaders now have an increased sense of urgency over supply-chain resilience; manufacturers in Europe and the United States are considering backups such as local sourcing.

[1] "China and the world: Inside the dynamics of a changing relationship," July 2019, McKinsey.com.

Fast decision making lays the foundation. When comparing the decision-making speeds of companies, we noted that fast decision makers will likely achieve 95 percent higher profitability in the next normal compared with their peers. Unfortunately, many traditional OEMs are still hampered by organizational silos and a hierarchical decision-making process, which is the opposite of what is needed in a fast-moving world.

Execution discipline forms the backbone for success. High-performing companies have management teams that are very disciplined when it comes to setting targets and negotiating key performance indicators (KPIs). Once a consensus is reached, there is little need to readjust afterward. Such teams hold frequent reviews in order to pinpoint minor deviations, explain them to the CEO, and make adjustments where necessary.

Clear accountability drives success. Historically, companies that have emerged stronger from a crisis have one thing in common: they do not hesitate to act when underperforming, even letting go of their top management team if necessary. For instance, one successful automotive OEM replaced 25 percent of its top managers during its transformation, boosting its market capitalization by a factor of four and raising operating profits by approximately ten percentage points within five years.

The automotive industry has reached a fork in the road: one path leads to reinvention and success, while the other maintains the current status quo. Business leaders will only have a brief window of opportunity to reimagine their core operations. To ensure their survival and success now and in the future, it's time for automotive industry players to act.

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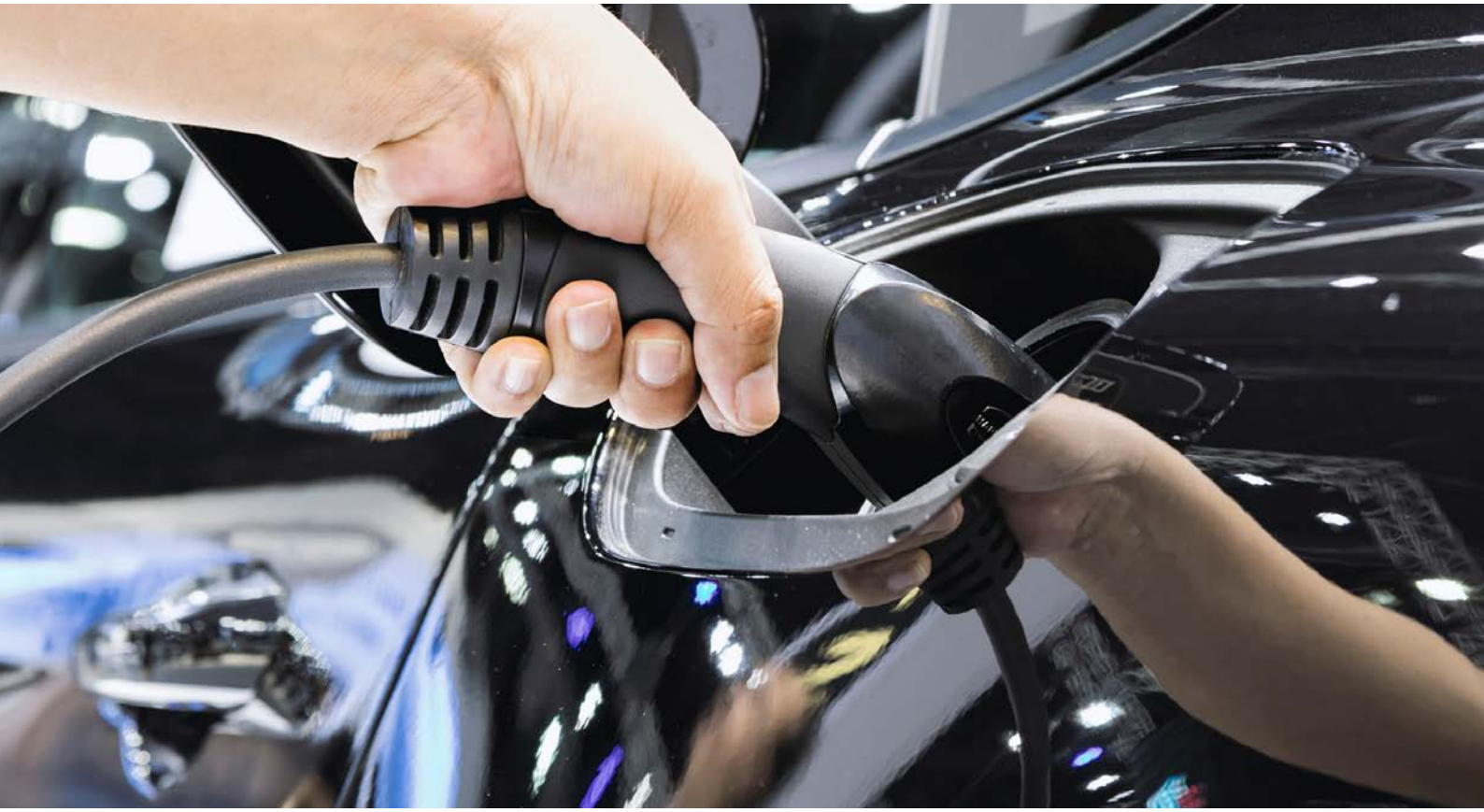
Designed by McKinsey Global Publishing

Electric mobility after the crisis: Why an auto slowdown won't hurt EV demand

Global auto sales plunged during the COVID-19 crisis, but electric mobility has remained remarkably resilient in some countries. Here's what's ahead for the electric-vehicle market.

September 2020

by Thomas Gersdorf, Russell Hensley, Patrick Hertzke, and Patrick Schaufuss



In 2019, electric mobility seemed poised to reach a tipping point. With more than two million electric vehicles (EVs) sold around the world, electric cars accounted for a record 2.5 percent of the global light-vehicle (LV) market.[1] Then the COVID-19 pandemic hit, endangering lives, shaking up supply chains and workforces, and shutting down factories. The economic slowdown has significantly disrupted the auto industry, causing rapid declines in LV sales.

Given the disruptions, previous predictions about EV growth are now obsolete. To create more accurate forward-looking perspectives, we examined the emerging developments that will shape the market over the coming years. We then conducted separate analyses of the EV markets in China, the European Union, and the United States, since trends might vary significantly by region. One of the most striking findings: the EV market is much more likely to see a quick recovery and strong growth in China and Europe than in the United States. Over the long term, EV market share is also more likely to increase in China and Europe.

COVID-19 crisis has significantly influenced major demand drivers

The COVID-19 crisis presents the greatest challenge to the global economy since World War II and has already exacted a heavy toll on the auto sector. Within the LV market, global sales for 2020 are currently expected to decline 20 to 25 percent from prepandemic forecasts in a virus-contained scenario (A3).[2] In the hardest-hit countries, the crisis could force staggering drops of up to 45 percent in LV sales for the year.

When considering the impact of the COVID-19 crisis on EV sales, including battery-powered EVs and plug-in hybrid EVs, we focused on developments in the following areas:

— *Macroeconomic environment.* The COVID-19 pandemic has not only decreased consumer purchasing power, but has also contributed to a significant drop in oil prices and, consequently, lower gasoline prices. For traditional vehicles with internal combustion engines (ICEs), the drop in gasoline prices will decrease the total cost of ownership. Although EVs will still have lower total costs of ownership than traditional ICE vehicles do in most segments, the advantage will not be as great, and that shift could influence sales. The impact of lower oil prices will vary by country, however, because of differences in tax policies. For instance, if the price of a barrel of crude oil decreased from $60 to $30, gasoline would become about 35 percent cheaper in the United States. In Europe, by contrast, the same drop would only reduce gasoline prices by 15 percent because of higher taxes on fuel sales and consumption.

— *Government policies and regulations.* Market dynamics are strongly driven by CO_2-emission limits, since they encourage OEMs to manufacture more fuel-efficient vehicles. Likewise, government incentives, such as purchase-price subsidies and tax exemptions, have a major effect on consumer demand. The COVID-19 crisis has already prompted some changes in both emission regulations and incentives. For instance, many local and federal governments have increased consumer incentives for EV purchases, often as part of stimulus programs designed to soften the economic impact of the pandemic. In Germany, for example, purchase-price subsidies for new EVs can amount to more than $10,000 per vehicle. In China, the purchase-price subsidy currently ranges from 16,200 to 22,500 renminbi (approximately $2,350 to $3,265) by car, depending on its range.[3]

— *Technology and infrastructure.* In addition to instituting monetary subsidies for EV purchases, several governments are investing in charging infrastructure as part of their economic-stimulus programs. They range from direct investments for public charging stations to subsidies for the installation of private charging stations at homes and workplaces. For example, China committed more than $1.4 billion in April 2020 to subsidize the construction of charging stations, on top of existing programs that promote the sale of EVs.

[1] Sales figures are from EV-volumes.com, IHS Markit, and MarkLines.
[2] For more on potential virus recovery and economic scenarios, see "Crushing coronavirus uncertainty: The big 'unlock' for our economies," May 13, 2020, McKinsey.com.
[3] Up to a vehicle base price of 300,000 renminbi.

The EV market is much more likely to see a quick recovery and strong growth in China and Europe than in the United States.

— *EV offerings.* The pandemic has shuttered plants and halted auto-assembly lines around the world. As OEMs prepare for reopening, some are prioritizing EV production either to meet the expected strong demand or to fulfill regulatory requirements, such as the European Union's strict target for CO_2 emissions. In contrast, some US-based OEMs are delaying production of upcoming EV models.

— *Consumer demand.* For many countries, consumer demand for EVs has remained relatively stable during the crisis when compared with demand for other vehicles. While the overall number of EV sales has declined in China and Europe, the market share for EVs has risen. In the United States, however, consumer demand for EVs has dropped. Globally, EV manufacturers that offer online sales have seen particularly high demand, since lockdown measures meant to control the spread of COVID-19 have kept people at home. For instance, Tesla has been shifting to an online-only sales model and was the only OEM to increase sales in March 2020.

Positive momentum in China and Europe; slowdown in the United States

Given the regional differences in the spread of COVID-19 and varying government responses, we conducted separate analyses for the three key markets that represent 94 percent of global EV sales[4]: China, Europe, and the United States. Exhibit 1 describes the major developments that we expect in each market for macroeconomic trends, government regulations and policies, technology and infrastructure, EV models, and EV supply.

Of course, we cannot be certain that the predicted developments will materialize as expected. Therefore, we created different scenarios for each region. In one, the overall LV market recovers quickly from the impact of the COVID-19 crisis, and growth in EV market share accelerates. In the second scenario, the overall LV market is slow to recover, and growth in EV market share slows. Based on our analyses, we expect that the positive-growth scenario is most likely in China and Europe. In the United States, by contrast, we expect that the slowdown scenario is the most likely (Exhibit 2).

China: Quick recovery, with sales accelerating by late 2020

China is by far the largest EV market in the world, with 1.2 million EVs sold in 2019. The country's quick containment of the COVID-19 pandemic and its economic rebound have contributed to a robust, developing EV ecosystem. Many EV start-ups are pushing new, mostly locally designed EV models into the market.

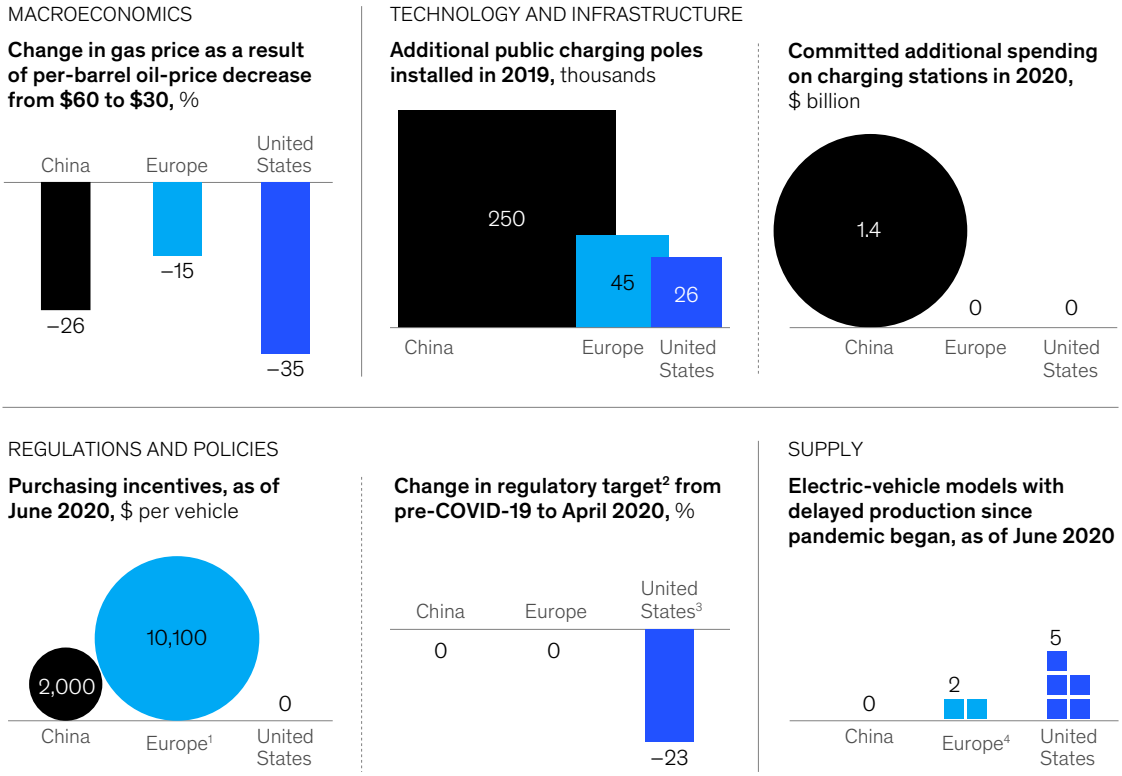
China also benefits from government policies designed to support EV growth. Some of them were in place before the pandemic, partly because officials were concerned that EV market-share growth decelerated from 2018 to 2019. For instance, China had established strong federal-fleet-emission targets and created a system in which OEMs received emission credits for

[4] The percentage is for global sales of battery-powered electric vehicles and plug-in hybrid electric vehicles in the second quarter of 2020.

Exhibit 1

Multiple drivers will shape the future electric-vehicle market, but their impact will vary by region.

Key drivers by selected focus areas

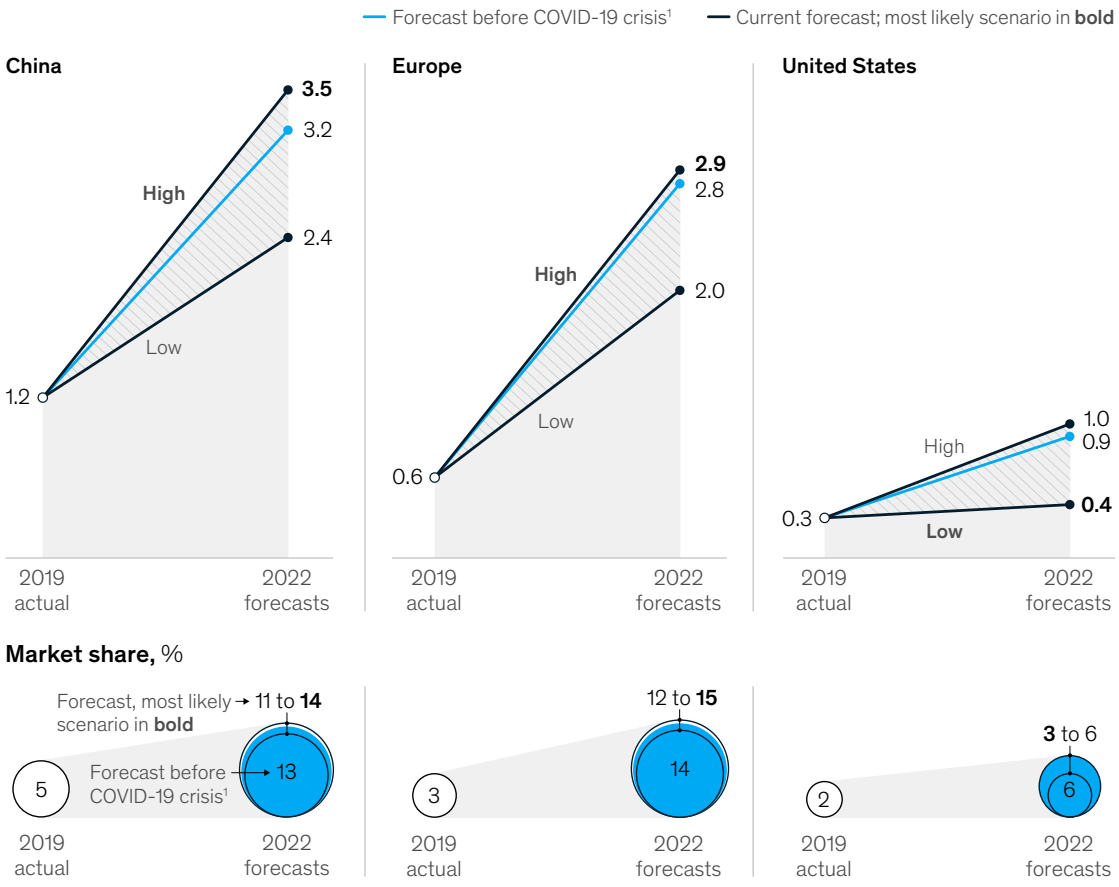


[1]Total purchasing incentives in Germany; similar incentives have been enacted or are under consideration in other European countries.
[2]Target of grams of CO_2/kilometer.
[3]2025 US federal-fleet-consumption target.
[4]Both model launches by US-based OEMs.
Source: *Autozeitung;* Electrek; electrive.com; European Alternative Fuels Observatory; *Handelsblatt*; NBC Universal; Renewable Energy World; Statista; Vox Media; McKinsey analysis

EV sales in the United States had been slowing before the COVID-19 crisis, with annual growth decreasing from 80 percent in 2018 to 12 percent in 2019.

Exhibit 2

The 2022 electric-vehicle market shares in China and Europe—but not in the United States—might be slightly higher than the precrisis projections.



Note: Preliminary projections, as of June 5, 2020; includes battery-powered electric vehicles and plug-in hybrid electric vehicles (light-vehicle market).
[1]Per January 2020 IHS Markit Alternative Propulsion Forecast.
Source: IHS Markit; McKinsey Center for Future Mobility analysis

passenger cars, based on various features, such as energy efficiency and vehicle range. In addition to those policies, the government is attempting to stimulate EV sales by extending purchase subsidies of up to 22,500 renminbi,[5] which were about to expire, through 2022. The government has also recently exempted EVs from the purchase tax.

Even with those incentives, the COVID-19 crisis has significantly affected EV sales in China. Only 100,000 units were sold in June 2020, compared with 196,000 in June 2019. That said, the EV market share in China has slightly increased to 4.4 percent in June 2020. Government incentives may contribute to even stronger market-share growth in the second half of 2020. For instance, China has long had license-plate quotas to limit the number of new vehicles on the road to reduce pollution. In several large Chinese cities where EVs are already popular, local governments are limiting new license-plate registrations to EVs and lifting restrictions on the purchase of new EVs.

[5] Depending on the range of the electric vehicle, up to a vehicle base price of 300,000 renminbi (approximately $43,540); not for imported EVs.

Overall, we expect that the number of EVs sold in China to potentially increase from 1.2 million in 2019 to between 2.4 million and 3.5 million in 2022—about 300,000 more in the most likely scenario than predicted before the COVID-19 crisis. With that shift, the EV market share in China would rise to 11–14 percent, from 5 percent.

Beijing's policies toward stimulating electric mobility in recent years have also helped create a crowded market, with numerous domestic EV makers and start-ups. The pandemic is likely to hasten consolidation of Chinese brands in 2022 and 2023. For instance, a Chinese EV maker planning its entry into the US market recently announced the suspension of its operations because of funding and operational problems brought on by the COVID-19 crisis. Several other players could follow, leading to consolidation and a smaller number of strong EV players in the Chinese market.

Europe: Positive momentum, with emission regulations potentially pushing market share higher by 2022

Despite the COVID-19 pandemic, European leaders have maintained a strict fleetwide CO_2-emission target of 95 grams of CO_2 per kilometer by 2021. Many major European-based OEMs have publicly committed to reaching that target and have rolled out an unprecedented number of battery-powered-EV and plug-in hybrid-EV models. By our count, they introduced 42 models in the first quarter of 2020 alone.

European governments have introduced new purchase subsidies, tax breaks, or a combination of incentives to encourage EV adoption and promote green mobility. While they implemented those policies to improve emissions, they are also responding to increased consumer concerns about sustainability and environmental issues. The incentives (such as Germany's subsidies toward the purchase of an EV), combined with the increase in EV models, has led to soaring consumer demand—despite the continued COVID-19 pandemic. For example, vehicle registrations for plug-in hybrid EVs and battery-powered EVs in Germany in the first half of 2020 increased by 200 percent and 43 percent, respectively, over the first half of 2019.

While the rebound from the COVID-19 crisis will differ by country, we expect that Europe is likely to make a quick recovery. Overall, European EV sales will potentially increase from 600,000 in 2019 to between 2.0 million and 2.9 million in 2022. Europe's EV market share is also increasing, in line with trends that were occurring before the COVID-19 crisis. The market share rose from 3 percent in 2019 to 7 percent by June 2020. By 2022, we expect that EVs may have a 12–15 percent market share in Europe—slightly higher than the precrisis projection in the most likely scenario.

United States: Stagnating sales, potentially pushing 2022 market share below precrisis demand scenarios

The US EV market looks vastly different from that in China or Europe. As in China, EV sales in the United States had been slowing before the COVID-19 crisis, with annual growth decreasing from 80 percent in 2018 to 12 percent in 2019. The country's slowing economy during the pandemic and the subsequent decrease in consumer spending are contributing to a lackluster EV market. Moreover, low demand for oil—and bottomed-out oil prices—make ICE vehicles cheaper than EVs to operate in the United States, since gasoline taxes are relatively low compared with those of most other countries.

Recent regulatory changes are also stymieing the large-scale adoption of EVs in the United States. The US federal government plans to decrease the fuel-economy standard to 40.4 miles per gallon by 2026 and is relaxing CO_2-emission targets. Although some states have adopted a stricter low-emission standard, such as the one in California, the current regulatory environment will provide fewer incentives for purchasing or manufacturing EVs.

A number of US-based OEMs have recently delayed the start of production on new EV models (as of May 2020, they had postponed the introduction of at least five). Consequently, we expect that EV sales may only increase slightly, going from 300,000

units sold in 2019 to between 400,000 (in the most likely scenario) up to 1.0 million in 2022. Growth in EV market share is also slowing significantly in the United States. It fell from 2 percent in the fourth quarter of 2019 to 1.3 percent in April 2020 before reaching 2.4 percent in June 2020. The projected 2022 market share of 3 to 6 percent is below precrisis expectations.

Long-term market dynamics

In addition to evaluating short-term changes, we also wanted to understand long-term trends for EVs. Would they see continued worldwide growth? And would regional differences continue to persist?

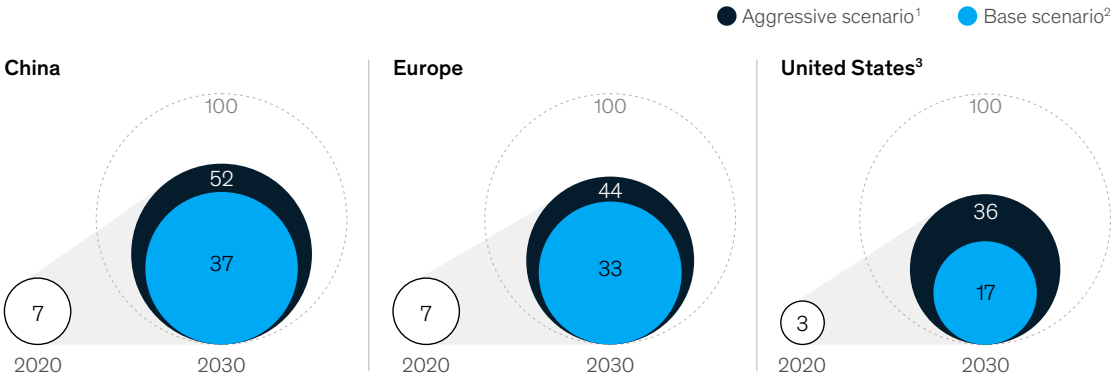
If the current tailwinds for EVs in China and Europe persist, electric mobility could emerge from the COVID-19 crisis in an even stronger position than precrisis estimates had predicted. In fact, regulations and incentives will likely propel EV market share[6] in China to roughly 35 to 50 percent and in Europe to 35 to 45 percent by 2030, with the post-COVID market environment making the aggressive scenario more likely (Exhibit 3).

There is more uncertainty about long-term trends in the US market because of regulatory headwinds and macroeconomic challenges; these could also change in the next 12 to 18 months, since the economic and regulatory outlook is also highly uncertain. While the EV market share in the United States will likely increase, the pace of its growth will likely be slower than seen in China or Europe, only reaching around 15 to 35 percent by 2030. The exact developments will largely depend on oil prices and monetary incentives for EV purchases, since the market is highly responsive to changes in those areas.

Exhibit 3

Growth in electric-vehicle market share will vary by region through 2030.

Projected electric-vehicle share of light-vehicle market, %



Note: Preliminary projections, as of June 5, 2020; includes battery-powered electric vehicles and plug-in hybrid electric vehicles (light-vehicle market).
[1]Assumptions include China meeting State Council emission targets, Europe missing 2020 emission-reduction targets and accelerating regulatory targets after 2025, and United States increasing adoption of California Air Resources Board (CARB) mandates, with consumer demand slowing adoption after 2025.
[2]Assumptions include China meeting State Council emissions targets, Europe missing 2020 emission-reduction targets and extending CO_2 limits proposed in November 2017 beyond 2025, and United States increasing adoption of CARB mandates.
[3]Decreased oil prices likely to diminish electric-vehicle market share by another 5% (to 12% in base scenario and 31% in aggressive scenario).
Source: McKinsey Center for Future Mobility analysis

[6] Including battery-powered electric vehicles and plug-in hybrid electric vehicles.

Beyond taking short-term actions to get businesses back on track, automakers and their suppliers will need to understand market dynamics, including regulatory and competitive trends, as we move towards the next normal. In addition to increasing EV adoption in some markets, the COVID-19 pandemic could have large-scale implications on how cars are sold and how profitable they can be. For example, with the pandemic preventing or discouraging consumers from going to showrooms, online sales of EVs could soar. While much uncertainty still persists, one thing seems clear: the future of global electric mobility is likely to emerge even brighter than before.

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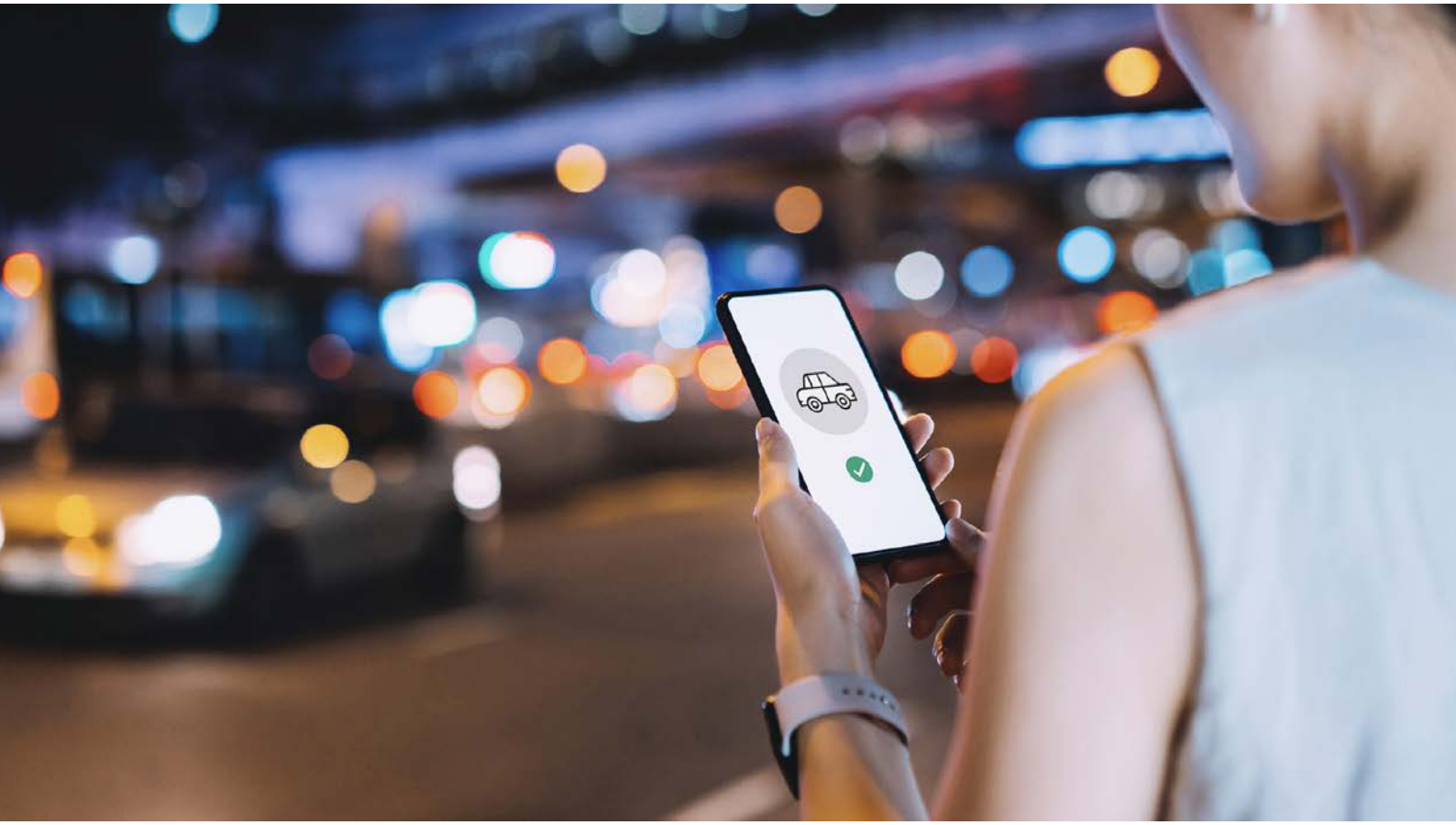
Designed by McKinsey Global Publishing

Why shared mobility is poised to make a comeback after the crisis

In a pandemic, passengers are wary of shared mobility. However, insights gleaned from our new global auto consumer survey can help pave the way toward a strong recovery—if done right.

July 2020

by Lennart Andersson, Andreas Gläfke, Timo Möller, and Tobias Schneiderbauer



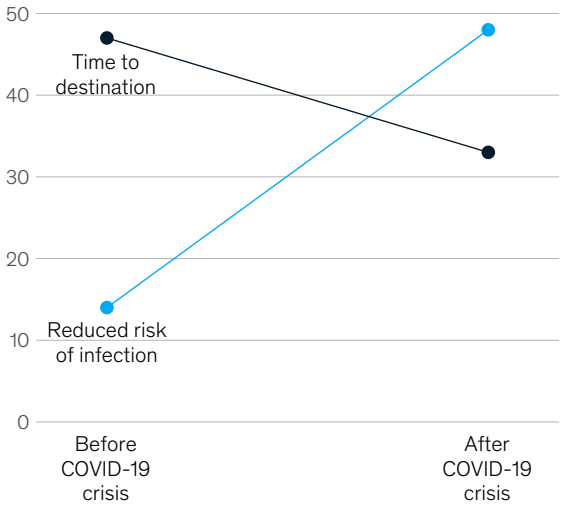
Within a matter of months, the global coronavirus pandemic has disrupted economies and afflicted millions of patients around the world. With many governments instituting lockdown measures, people practicing physical distancing, and case counts continuing to mount in some cities, very few people are using shared modes of transportation—for instance, real-time ridesharing—and the industry has very quickly lost both passengers and profits.

To determine if the drop in shared mobility might persist over the long term, we researched the sector and examined data from the ongoing McKinsey Global COVID-19 Automotive Consumer Survey. The first two waves of this survey, which were conducted in May 2020, each included more than 8,000 respondents spanning seven countries.[1] Our findings show that consumers are indeed wary of shared mobility, given the risk of viral infection, and mobility-service providers (MSPs) must take decisive steps to address their concerns. With the right strategy, they can make a strong comeback and potentially return to prepandemic service levels. Here's a summary of our findings, as well as a playbook for moving to the next normal.

Exhibit 1

Reduced risk of infection is the most important factor when consumers are choosing a transportation mode.

Importance of criteria when choosing mobility mode, % of respondents



Source: McKinsey Global COVID-19 Automotive Consumer Survey (first 2 parts of ongoing survey conducted May 9–17 and May 23–31, 2020, respectively—each with >8,000 respondents across 7 countries)

Shifting priorities in the age of COVID-19

The coronavirus crisis has triggered a dramatic shift in consumer priorities about mobility. In part one of our survey, 47 percent of respondents state that the time to destination was an important consideration before the pandemic; only 14 percent state that reducing the risk of infections was important (Exhibit 1). In the aftermath of the COVID-19 pandemic, the ability to reduce viral infection is now the most common consideration, cited by almost half of all respondents. The time to destination is cited as an important consideration by only 33 percent of respondents. As an indication that staying healthy remains top of mind for global consumers, that sentiment remained largely unchanged—at 45 percent—in part two of our survey, conducted two weeks later.

The new consumer concerns have had a significant impact on the perception of MSPs. Only 5 to 8 percent of our survey respondents think that carsharing, ridesharing, or shared micromobility are safe, from a health standpoint (Exhibit 2). Only 7 percent feel public transportation is safe. In contrast, 81 percent of respondents consider private vehicles safe. Given those safety concerns, people have changed their mobility patterns tremendously. For example, ride-hailing companies in multiple geographies have experienced 60 to 70 percent declines in passengers during the COVID-19 crisis.

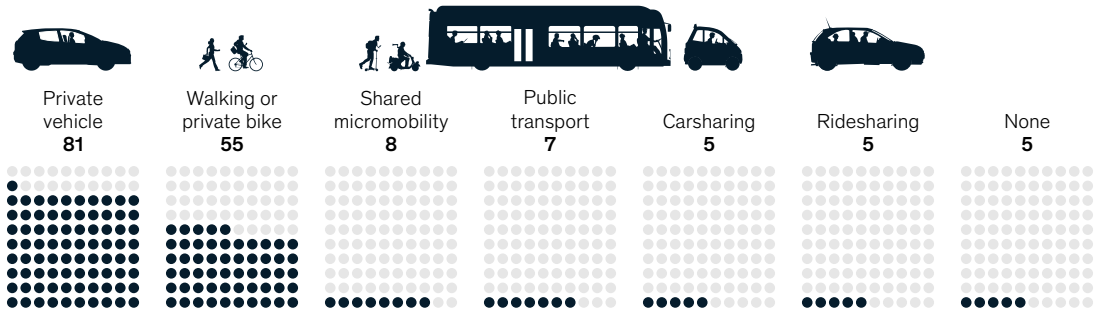
Consumers may not always remain averse to shared mobility, however. In fact, people who want to avoid COVID-19 might eventually come to view ridesharing as a good alternative to more congested forms of

[1] The McKinsey Global COVID-19 Automotive Consumer Survey is ongoing. The first two waves were conducted from May 9 to May 17 and from May 23 to May 31, 2020, respectively.

Exhibit 2

Less than 10 percent of survey respondents believe carsharing, ridesharing, or shared micromobility to be safe.

Perceived health safety of mobility modes, % of respondents



Source: McKinsey Global COVID-19 Automotive Consumer Survey (first 2 parts of ongoing survey conducted May 9–17 and May 23–31, 2020, respectively—each with >8,000 respondents across 7 countries)

mobility that make physical distancing difficult, such as public transportation.

To capture potential opportunities as economies gradually reopen, MSPs need to know how to react to the current challenges while preparing for the next normal. Moreover, they should be ready for not only the potential next waves of COVID-19 but also other infections that might occur. Acting quickly and having a plan tailored to specific regional markets could be important.

The recovery of MSPs is more than an economic concern. It has broader societal implications, since shared mobility can help reduce traffic congestion, air pollution, and greenhouse-gas emissions. The recovery of MSPs is also relevant to the OEMs and suppliers that create vehicles and components, since they may need to improve their designs to increase safety. City and local officials also have an interest in MSP recovery, since shared mobility could enhance life in other ways, such as making it easier to get around. To encourage MSP growth, officials must therefore monitor the industry closely and create appropriate regulations.

A playbook for mobility-service providers responding to a global crisis

We believe that MSPs can respond to the current COVID-19 pandemic and future crises by taking several actions split into three phases (Exhibit 3).

Within days, respond at once

MSPs have already taken immediate steps to respond to the COVID-19 crisis, and that model will serve them well if similar events occur in the future. As passenger demand plummeted and lockdowns challenged established work practices, MSP-industry leaders turned their immediate focus to surviving the turmoil without inflicting long-term damage on their businesses. Companies defined standard response protocols for different scenarios and implemented immediate safety measures, such as suspending pooled-vehicle services. They also helped keep their drivers financially solvent with support packages worth more than $10 million. By retaining drivers, companies can more quickly resume normal operations as lockdowns end.

Within weeks, cope with the crisis

As the number of COVID-19 cases decreases in some areas and countries begin to reopen, MSPs

Exhibit 3

A playbook can help mobility-service providers respond to the COVID-19 crisis.

Within days

- Define standard response protocols for different scenarios
- Implement immediate safety measures (eg, suspending pooled services)
- Help drivers pay their bills through financial support
- Introduce remote-work practices
- Adjust to epidemiological reality in addition to local regulations

Within weeks

- Select and implement new business tactics
- Collaborate with local governments (eg, identify special offers that can both help community and increase utilization)
- Adjust loyalty programs so customers aren't penalized for suspending ridership
- Redefine HR and payroll policies
- Adjust governance and organization, basing reactions on knowledge of local market and regional differences

Within months

- Optimize portfolios, prioritizing right kind of services and regions and allocating resources accordingly
- Optimize operational efficiency for next normal
- Build partnerships between customers and drivers that take whole journey into account
- Pursue opportunities to grow through M&A

should find ways to return to normal operating conditions while maintaining safety. Although consumers perceive private vehicles as the most hygienic transport option, they aren't available to everyone. In consequence, MSPs should ramp up marketing efforts, even though many people are still concerned about the safety of shared mobility. The message should be that ride-hailing and carsharing services are viable alternatives to private-car ownership and public transportation.

Companies may also encourage robust levels of utilization through other measures, such as converting taxis to delivery vehicles for pharmacies and other stores. Our survey shows the potential for revenue sources arising from leisure activities, since 45 percent of respondents can imagine using vehicles to connect safely with the outside world—including going to drive-in theaters, restaurants, and shopping centers.

In addition to deploying thoughtful marketing campaigns and, if necessary, implementing new business strategies, it is also critical for MSPs to deal with cash- and liquidity-management issues. Companies should quickly shutter businesses that remain unprofitable while also creating potential new revenue streams, such as those stemming from innovative business partnerships. For example, after a national supermarket chain was overwhelmed by demand for home deliveries, it partnered with a ridesharing company to make next-day deliveries of food and essentials for orders placed online. In another example, a public-transit agency is using a major mobility player's mobile platform to give its users access to ridesharing on demand.

Months later, thrive in the next normal

Long after the COVID-19 crisis fades away, its memory will leave a lasting impact on consumers, whose personal and professional lives have been disrupted. Nevertheless, if MSPs can reimagine their business models, we believe that they have the potential to make a strong comeback. After the pandemic, as consumers resume everyday activities, such as dining out and going to the theater, ridesharing services might even surpass their previous levels of popularity. According to our survey, 15 percent of respondents expect to use ride-hailing services regularly after the pandemic; before the crisis, that figure was 14 percent.

The road to recovery might be a long one, however. Even in China, where the crisis is mostly under control, less than one-fifth of consumers in the second part of our survey say that they would consider ride hailing safe for their health—only a slight increase from the 15 percent reported in part one of the survey, conducted two weeks earlier. Despite these concerns, ride hailers in China are reporting early signs of recovery after seeing their number of passengers plummet in February 2020.

With so much uncertainty in the market, MSPs would be wise to prioritize the right kinds of services for different regions and allocate resources accordingly. That may even include entering some nonmobility businesses, such as grocery e-commerce and package delivery, for added growth. Established players and new entrants have the opportunity to grow through M&A. In fact, the industry already shows signs of accelerated consolidation via M&A, particularly in the micromobility space. For instance, a European micromobility provider acquired an e-scooter business earlier this year, while a US-based mobility company acquired a global transportation company's bikesharing brand.

Safety is—and will remain—paramount

Throughout all phases of the pandemic, safety will be a top priority. During the first days of the crisis, MSPs have implemented a range of quick safety improvements that will persist, and they may soon add other measures. Those efforts span the entire customer journey (Exhibit 4):

— *Before the trip.* Globally, most providers canceled their pooled services because of the pandemic. When customers book a trip, service providers notify them that their cars are freshly sanitized and ventilated.

— *During the trip.* MSPs require all drivers and passengers to wear masks. Image-recognition technology can be used to verify that the drivers remain masked throughout the journey. In addition, separating driver and passengers with a protective sheet is a critical measure for MSPs:

Exhibit 4

Mobility players have implemented measures to improve hygiene across the entire customer journey.

Examples of safety measures implemented in customer journey

No pooled trips Pooled trips canceled, leaving only solo rides

Safety message Upon booking confirmation, app informs user that car has been freshly sanitized and ventilated

Masks Drivers and riders required to wear masks at all times; masks also mandatory by law in several jurisdictions (major ridesharing player has announced use of new technology to check for masks)

Protective sheet Drivers separated from passengers by plastic sheets that create compartments

Ventilation Drivers keep their windows open to improve air circulation

Cashless payment Cash-payment options eliminated; payment by phone or other cashless means mandatory

Sanitation Cars sanitized after each trip

nearly 30 percent of our survey respondents said that such measures would increase their likelihood of booking a ride. Other safeguards include regularly opening windows to improve ventilation.

— *After the trip.* MSPs shouldn't give customers the option to pay cash, since contactless digital payments are perceived as safer. Data management is important for MSPs; they may need to trace contacts in case of infections.

— *Between trips.* MSPs need to sanitize cars between trips. Our survey respondents see this as the most important measure the industry can take to protect them, with 52 percent saying that sanitization would increase their likelihood of using ride-hailing services.

The mobility industry can learn from the challenges presented by the COVID-19 crisis and make a strong recovery. However, players must first continue to overcome the immediate challenges presented by the crisis and make additional progress. There will be no going back to prepandemic life, so companies must look ahead and prepare to compete in the next normal. With the "firefighting" phases of the first weeks and months of the crisis now in the past, they must rethink their strategies and focus on partnerships, portfolio optimization, and enhanced vehicle design to enable safe mobility going forward (see sidebar, "Safe vehicle design").

Preparing for the next normal isn't only relevant to MSPs. OEMs and suppliers have an opportunity to work with MSPs to promote thoughtful design of purpose-built vehicles that are safer for passengers. That effort can be part of a larger shift toward more customer-centric vehicle design. Some of the rideshare cars' design changes, such as new, more hygienic interior materials, might also be desirable in private vehicles.

In other shifts related to the next normal, the need for better protection may create a new after-sales market that involves retrofitting hygiene solutions to current cars. In addition, insurance companies might need to prepare by devising new policies that consider the risk of infections. Finally, local governments will need to design the mobility concepts that take us into the next normal—such as those that address passenger health and safety. They must also develop regulations for a staged return to greater mobility after lockdowns end, including mobility in public transportation, carsharing, and ridesharing.

We believe that shared mobility can recover strongly from the current crisis, but it's crucial for leaders to determine which protective measures are most effective and deploy them accordingly. Our hope is that the insights in this article will help government and business leaders devise smart, targeted strategies to combat future outbreaks of infectious diseases.

Shared mobility can recover strongly from the current crisis, but it's crucial for leaders to determine which protective measures are most effective and deploy them.

Safe vehicle design

Improving on the measures mentioned in the article, better vehicle design can help make vehicles more hygienic over the long term (exhibit). The COVID-19 crisis may spur forward-thinking industry leaders to make such enhancements more quickly than planned.

First, companies might optimize interior layouts to ensure a minimum distance between passengers. That could involve adjusting seat positions and installing protective shields between passenger seats. In fact, nearly 45 percent of respondents to the McKinsey Global COVID-19 Automotive Consumer Survey considered those measures to be important.[1] Flexible designs such as those are crucial in helping mobility-service providers (MSPs) react to a crisis.

In addition, within car cabins, companies can integrate interior surfaces that better absorb bacteria. For instance, innovative new films offer antibacterial properties without compromising an interior's look and feel. (In fact, some biomedical applications already use this technology.) By using robust interior materials and technologies, MSPs can enable more thorough and frequent sanitizing between shifts or during breaks.

Automakers can also look outside the industry for examples of germ-fighting enhancements. For example, some airports have begun utilizing ultraviolet (UV) technology to disinfect luggage and other surfaces. In another example, a major public-transit agency is piloting the use of high-intensity UV lamps to disinfect city buses, trains, and subway stations. In fact, some car manufacturers have already started to roll out new technologies to fight the coronavirus. For instance, an automaker added a software patch that enables some of its cars to be heated to temperatures high enough to kill viruses.

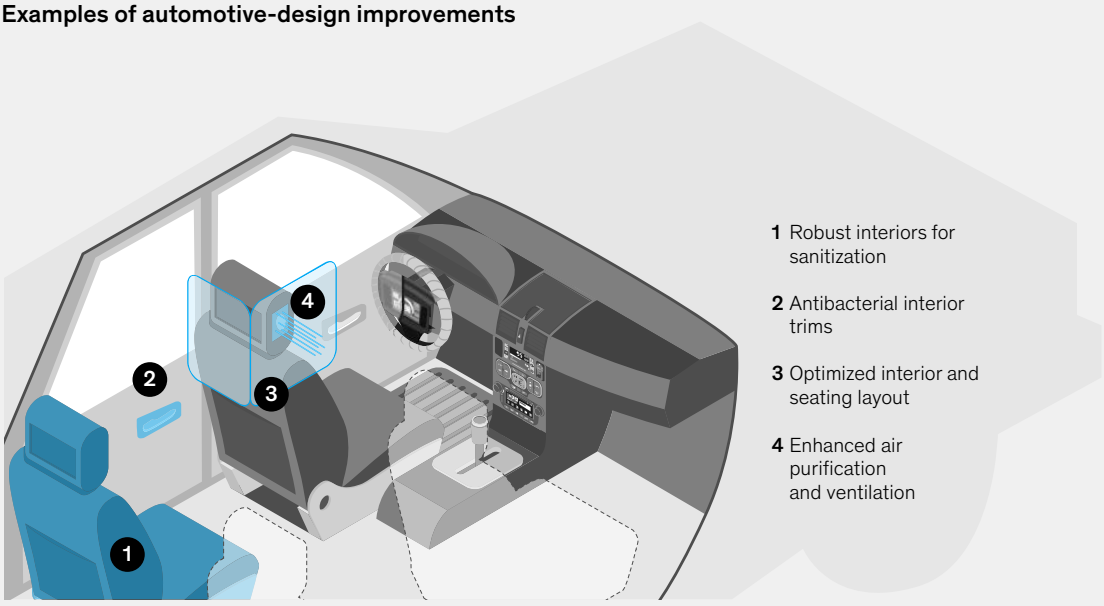
Improving the filtration of air from outside and within a vehicle's cabin will be critical. Companies could, for example, reduce the recirculation of stale air by using headrests with integrated air vents. An electric-vehicle manufacturer has installed HEPA filtration systems that it claims can effectively remove pollutants, such as pollen and bacteria, from the air. Such enhancements can protect riders' heath while reassuring them that shared mobility can be used safely, even in the context of a global pandemic.

[1] The McKinsey Global COVID-19 Automotive Consumer Survey is ongoing. The first two waves were conducted from May 9 to May 17 and from May 23 to May 31, 2020, respectively. Each included more than 8,000 respondents spanning seven countries.

Exhibit

Improved designs can make shared mobility safer for drivers and passengers alike.

Examples of automotive-design improvements



1 Robust interiors for sanitization

2 Antibacterial interior trims

3 Optimized interior and seating layout

4 Enhanced air purification and ventilation

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Designed by Global Editorial Services

The future of micro-mobility: Ridership and revenue after a crisis

The COVID-19 crisis is causing serious disruptions to the multibilliondollar micromobility industry. Our analysis indicates that a full recovery is possible, as long as companies prepare for the next normal.

July 2020

by Kersten Heineke, Benedikt Kloss, and Darius Scurtu

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The COVID-19 pandemic has affected millions of people worldwide, bankrupted businesses, and plunged the global economy into crisis. While lockdown measures and shelter-at-home orders are helping contain the coronavirus, they have also brought severe financial hardship. Amid a new reality of working from home, canceling trips, and even forgoing outings to restaurants and grocery stores, the micromobility industry—encompassing a range of lightweight vehicles such as bicycles, e-scooters, and mopeds—is facing devasting declines in ridership and revenue.

The blow to micromobility came just as the industry was accelerating. In 2019, a banner year, our models predicted that the micromobility industry would be a $300 billion to $500 billion market by 2030. Our benchmark assessment of micromobility's potential impact on the city of Munich also suggested good things ahead. Then, the pandemic hit. With the number of passenger-kilometers traveled declining 50 to 60 percent worldwide since the onset of the COVID-19 crisis, use of micromobility solutions has declined dramatically. To determine the full impact of the pandemic on this sector, as well as on future developments, we examined micromobility over three time horizons (Exhibit 1):

— *Short term.* What effect is the global lockdown having on micromobility now?

— *Medium term.* Will we see a complete recovery, and what will the next normal look like?

— *Long term.* What effects will the pandemic have on our 2030 market modeling?

This article is part of a series on the future of mobility after the COVID-19 crisis.[1]

Short term: Spiked valuations and more bicycle lanes

In our short-term analysis, we examined the impact of the global pandemic on micromobility by examining the response of the industry itself, consumers, and cities.

Micromobility-service providers are struggling
The global lockdown is profoundly affecting service-provider valuations, workers employed in the sector, and the speed of industry consolidation. For example, the valuation of one company operating a worldwide network of e-bikes and e-scooters recently dropped by a reported 79 percent. Another provider halted operations in six US cities and all of its European markets, laying off 30 percent of its workforce. A third company cut working hours for 60 percent of its staff while supplying a streamlined fleet of its e-scooters to healthcare workers in Germany. The lockdown has also accelerated industry-consolidation moves. For example, a micromobility company recently acquired the e-bicycle and e-scooter business of a major ride-hailing company.

Consumer behavior is shifting rapidly
In response to measures to control the COVID-19 pandemic, such as shelter-at-home orders, local travel preferences are quickly changing. One example is the preference for longer trips. According to a US micromobility company that rents e-scooters, average trip distances have grown 26 percent since the start of the pandemic, with rides in some cities, such as Detroit, increasing by up to 60 percent. At a more detailed level, some cities are also experiencing a shift in consumer use cases. For instance, in San Francisco, the lockdown has caused a pronounced shift toward runs to the pharmacy and trips to restaurants to pick up food.

Cities are offering greater support for biking
Worldwide, the lockdown has driven new citywide policies. One major result is an increased focus on bicycle lanes. Consider the following:

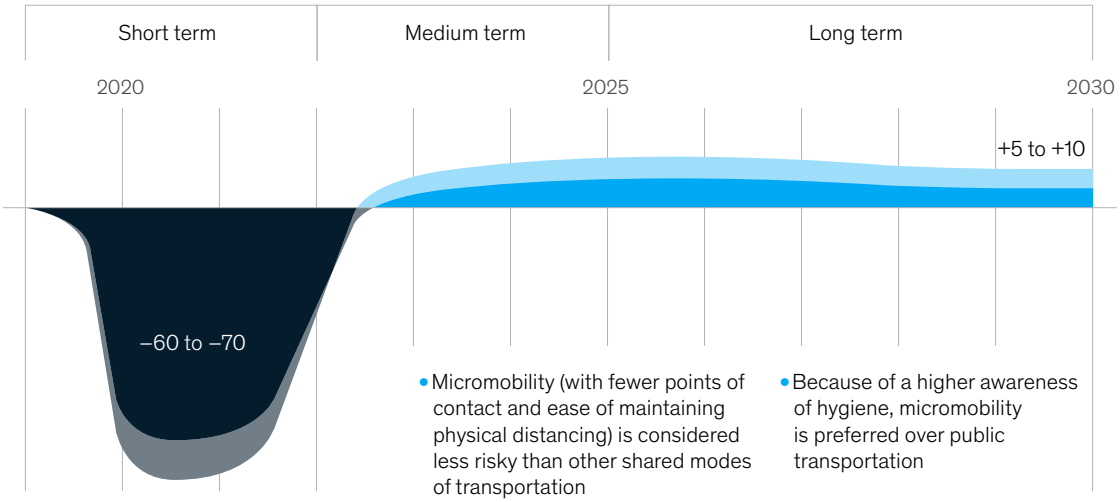
— Milan has announced that 35 kilometers of streets previously used by cars will be transitioned to walking and cycling lanes after the lockdown is lifted.

[1] Our analysis is part of an ongoing effort to recalibrate our perspective and modeling on mobility, taking into consideration both COVID-19-crisis and long-term trends. We integrated our micromobility modeling into the broader McKinsey mobility Modern Marketing Model (M3), which analyzes the current and future development and interaction of all modes of transportation over the next decade. By doing so, we can investigate the relationship between micromobility and other future mobility modes.

Exhibit 1

The micromobility sector is expected to make a strong postpandemic recovery.

Impact of COVID-19 crisis on global shared and private micromobility,[1] % passenger-kilometers traveled



- Lockdowns result in fewer commuting and leisure activities, limiting travel
- Hygiene laws result in short-term shutdowns
- Using shared transportation is a perceived health risk

- Micromobility (with fewer points of contact and ease of maintaining physical distancing) is considered less risky than other shared modes of transportation
- Lockdown causes changes in customer behavior and mobility patterns (more people try private micromobility modes for first time and take longer trips because of a shift in use cases)

- Because of a higher awareness of hygiene, micromobility is preferred over public transportation
- Quiet and green transportation modes that avoid congestion are preferred
- Cities deincentivize and regulate private-car travel while investing in bicycle infrastructure as an alternative

[1]Base-case modeling from 2019. The primary drivers of micromobility changes are listed below the chart; these are not exhaustive.

— Paris will convert 50 kilometers of lanes usually reserved for cars to bicycle lanes. It also plans to invest $325 million to update its bicycle network.

— Brussels is turning 40 kilometers of car lanes into cycle paths.

— Seattle permanently closed 30 kilometers of streets to most vehicles, providing more space for people to walk and bike following the lockdown.

— Montreal announced the creation of more than 320 kilometers of new pedestrian and bicycle paths across the city.

Midterm: Recovery and the next normal

As the pandemic wanes in some locations, it is natural to wonder when people will start to travel again. Based on an analysis of Apple iPhone data, the number of passenger-kilometers traveled by private and shared micromobility vehicles has decreased by an estimated 60 to 70 percent in Europe and the United States. Interestingly, the same data source already shows a U-shape recovery; extrapolating this trend indicates a recovery to precrisis levels of travel by 2021–22.

To determine if and when micromobility would recover, we conducted a global consumer survey in

May 2020. It included more than 7,000 respondents from seven global markets—China, France, Germany, Italy, Japan, the United Kingdom, and the United States. Our goal was to investigate consumer mobility behaviors and expectations before, during, and after the crisis.

According to our consumer survey, the use of micromobility might increase. It showed that the number of respondents willing to use micromobility in the next normal on a regular basis will increase by 9 percent for private micromobility and by 12 percent for shared micromobility compared to precrisis levels. Given these trends, we believe that private- and shared-micromobility solutions will experience a complete recovery in the number of passenger-kilometers traveled, with no significant drop from precrisis levels. We also believe that mobility in general will fully return to precrisis levels.

Some consumer priorities and usage patterns are changing

While the industry itself will persevere, micromobility will undoubtedly look different after the crisis as it enters the next normal. Take consumer behavior, for instance. Prior to the pandemic, our consumer surveys revealed that the main pain point felt by regular users of shared micromobility was the time to destination. Now, it is the risk of infection (Exhibit 2).

When asked in our May 2020 survey about measures that would increase the consumer likelihood of using shared-micromobility services, 47 percent of respondents cited regular disinfection of equipment, 43 percent said physical distancing from the previous or next user, and 31 percent said user-health checks.

While consumer concerns are changing, ridership preferences by age will likely remain static. In private micromobility, we expect to see a similar split across all age groups, precrisis and postcrisis (Exhibit 3). Currently, about half of all shared-micromobility users are younger than 34, with the fewest users older than 55. Based on our consumer surveys, we do not anticipate a change of this ratio in the postpandemic era.

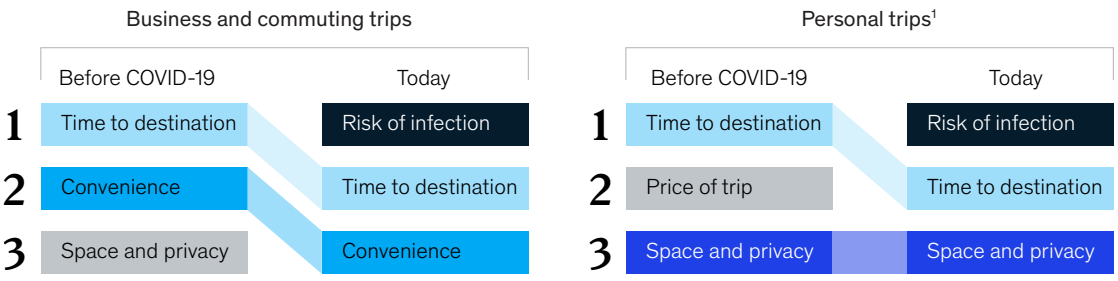
Mobility patterns will likely change

As seen during the COVID-19 crisis, average trip distances might increase, since people will use micromobility solutions more often when commuting. In our 2019 global ACES[2] consumer survey, less than 20 percent of all shared-micromobility trips typically involved commuting. However, this survey also indicated that more than 70 percent of respondents would consider buying a private e-scooter for everyday commutes to work or school. This shift could boost private ownership in the e-scooter market.

Exhibit 2

Our consumer survey reveals that risk of infection has become the top concern.

Main concerns when choosing shared micromobility, ranked by number of respondents



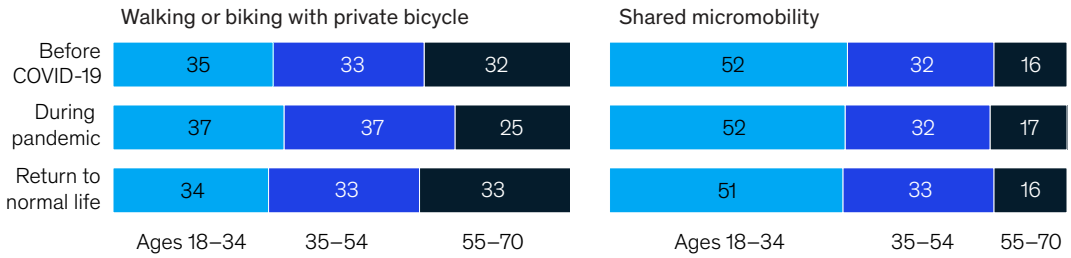
[1]Personal trips include those for leisure and vacations.

[2] Autonomous driving, connectivity, electrification, and shared mobility.

Exhibit 3

After the COVID-19 pandemic, we expect that ridership preference by age will likely remain static.

Private-bicycle and shared-micromobility[1] riders by age group, % of respondents[2]



Note: Figures may not sum to 100%, because of rounding.
[1]For example, a shared e-scooter, e-bike, or e-moped.
[2]Question: Do you use or anticipate using the following modes of transportation on a regular basis?

Industry consolidation will continue to accelerate
With drastic decreases in ridership and revenue, shared-micromobility providers find themselves in a more precarious position—and this could continue the accelerated consolidation of companies. In turn, greater acceleration could improve the business case for micromobility providers and increase profitability, given the synergies and scale-efficiency improvements that occur when buying larger volumes of vehicles, processing more payment transactions, and capturing greater back-office scale effects, along with a higher number of insurance fees. Furthermore, cities may reduce their permit fees to support micromobility as an alternative to private-car ownership after the COVID-19 crisis. For example, our analysis shows that the profitability of shared e-scooters could increase by up to five percentage points in the next normal (Exhibit 4).

Long term: More micromobility travel in the next normal

We believe that micromobility will emerge intact and thrive in the long term. Indeed, our estimates for 2030 predict a boost of 5 to 10 percent in the number of passenger-kilometers traveled compared with our base case. This increase will come from several trends.

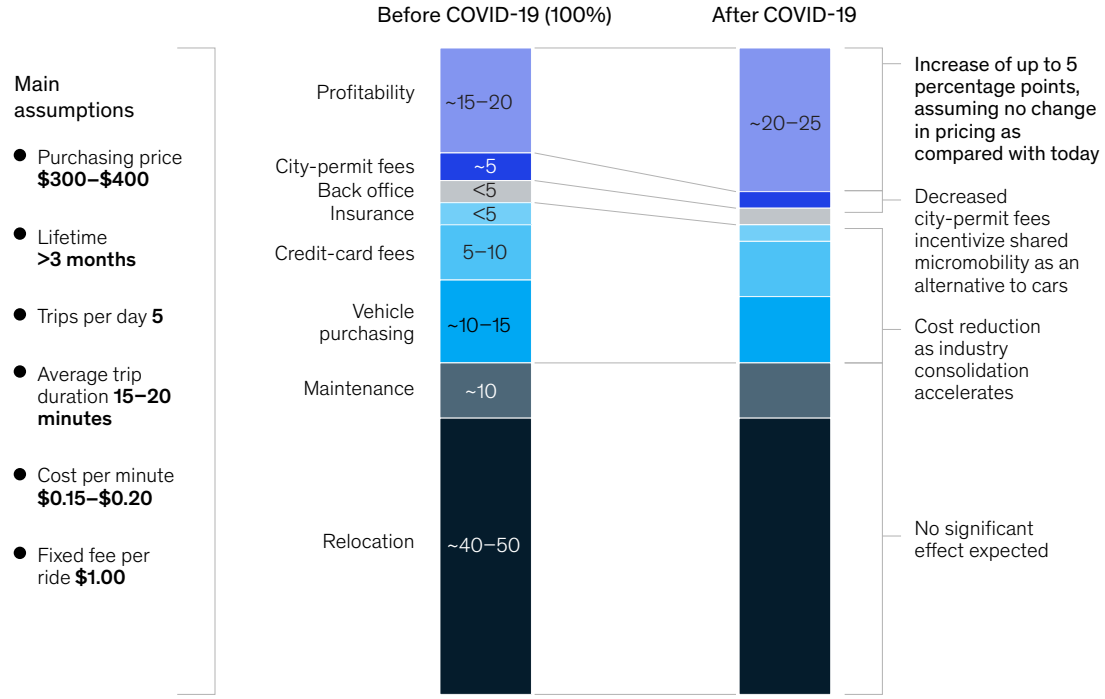
First, according to our consumer survey, people are now more willing to regularly use micromobility; in addition, average trip distances could increase, as observed during the COVID-19 crisis, leading to a higher revenue per trip. What's more, higher awareness about personal hygiene and physical distancing might encourage consumers to use micromobility, rather than public transportation, for short trips.

Other trends relate to private-car usage. This form of transport could increase in cities in the next normal as people practice physical distancing to prevent transmission of COVID-19. Overall, private cars are seen as a safer mode of travel, especially when compared with public transit. As noted earlier, cities might enact measures to deincentivize and regulate private-car ownership, such as instituting higher parking fees, taxes, and tolls. They might also invest more in biking infrastructure or even repurpose whole streets to incentivize micromobility use. Furthermore, following the example of Italy, the industry could lower up-front costs for consumers by establishing purchasing premiums for bicycles, e-scooters, and mopeds. They may also enact mileage allowances for those using micromobility for commuting.

Exhibit 4

Micromobility will likely increase in profitability in the next normal.

Estimated breakdown of costs per ride for a shared free-floating e-scooter, %



Source: Expert estimates and interviews; press and web research; McKinsey analysis

Finally, consumers could become more aware of the value of sustainable and noise-reducing transportation modes after experiencing them during lockdowns. Micromobility might thus emerge as a leading option for riders who want to protect the environment.

The global pandemic has transformed the way people think about travel, including micromobility. The short-term consequences have been profound, with micromobility declining as people reassess their transportation options. However, given current consumer sentiment, policy actions, and the potential for upside, we expect the industry to emerge stronger from this crisis.

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ACES 2019 survey: Can established auto manufacturers meet customer expectations for ACES?

Consumers believe that established automakers are well positioned to capitalize on ACES trends. Will they reach their full potential in a challenging market?

February 2020

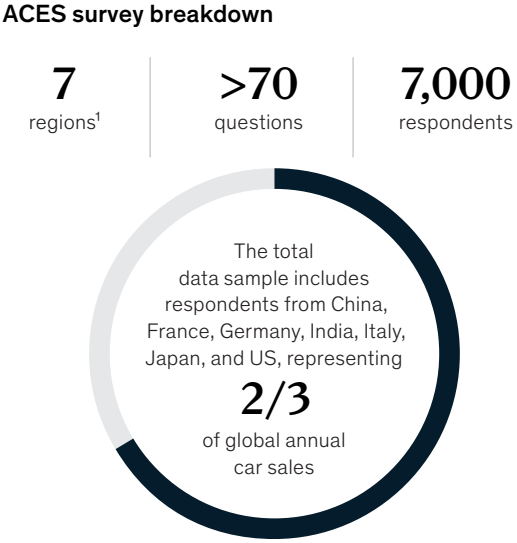
by Kersten Heineke, Daniel Holland-Letz, Matthias Kässer, Benedikt Kloss, and Thibaut Müller

Four disruptions—**A**utonomous driving, **C**onnected cars, **E**lectrified vehicles, and **S**hared mobility—have become the hottest topics in the automotive industry in recent years. McKinsey's 2019 ACES survey, which examined consumer mobility preferences worldwide, revealed that customers believe traditional OEMs are well qualified to drive innovation in these areas. That finding marks a big departure from previous surveys, where consumers stated that established OEMs lagged behind their Asian counterparts and start-ups in pursuing ACES trends.

Can established automakers truly gain the upper hand in the game of ACES? To answer this question, we took a close look at the 2019 survey results, including country-specific findings. Our analysis revealed that traditional OEMs are well positioned to become leaders in ACES because consumers have faith in their capabilities, particularly in Western markets. But all companies, including traditional OEMs, may encounter several challenges that could limit their gains from ACES.

Exhibit 1

The 2019 ACES Consumer Survey examined consumer attitudes about major mobility trends.



[1] Prior to 2019, the survey only included China, Germany, and US.

The ACES survey

McKinsey's 2019 ACES survey highlighted the urgency and importance of pursuing ACES trends. It involved more than 7,000 respondents in seven countries (China, France, Germany, India, Japan, the United Kingdom, and the United States) (Exhibit 1).[1] These locations account for approximately two-thirds of annual global new car sales.

Our survey included more than 70 questions about ACES trends. It was designed to allow numerous data cuts, including those for city type, gender, age, level of education, and income.

Customers trust traditional OEMs to succeed in ACES

In our 2018 survey, younger Chinese consumers were the most enthusiastic about ACES trends. This year, the survey revealed that Western customers are now more willing to explore ACES than in the past. Western customers also expressed a higher degree of trust that OEMs could deliver ACES capabilities.

Across countries, consumers valued safety more than any other vehicle feature, with 53 percent of respondents citing a desire for higher safety standards as their primary reason for wanting to replace an old car. A desire for a lower total cost of ownership came in second. Vehicle performance and design carried the least weight in the decision to purchase a new car—a finding that might force OEMs to focus on other differentiating features in the future.

Our survey results suggest that established OEMs may have an advantage as ACES trends accelerate because customers view them favorably. For instance, 66 percent of respondents stated that

[1] McKinsey has been conducting the ACES survey since 2014. In past years, it included about 3,000 respondents in China, Germany, and the United States.

established OEMs are the most likely to bring fully mature—and therefore safe—autonomous vehicles (AVs) to market. There was little variation across countries in this sentiment. Other important findings that suggest OEMs may have an advantage with ACES include the following:

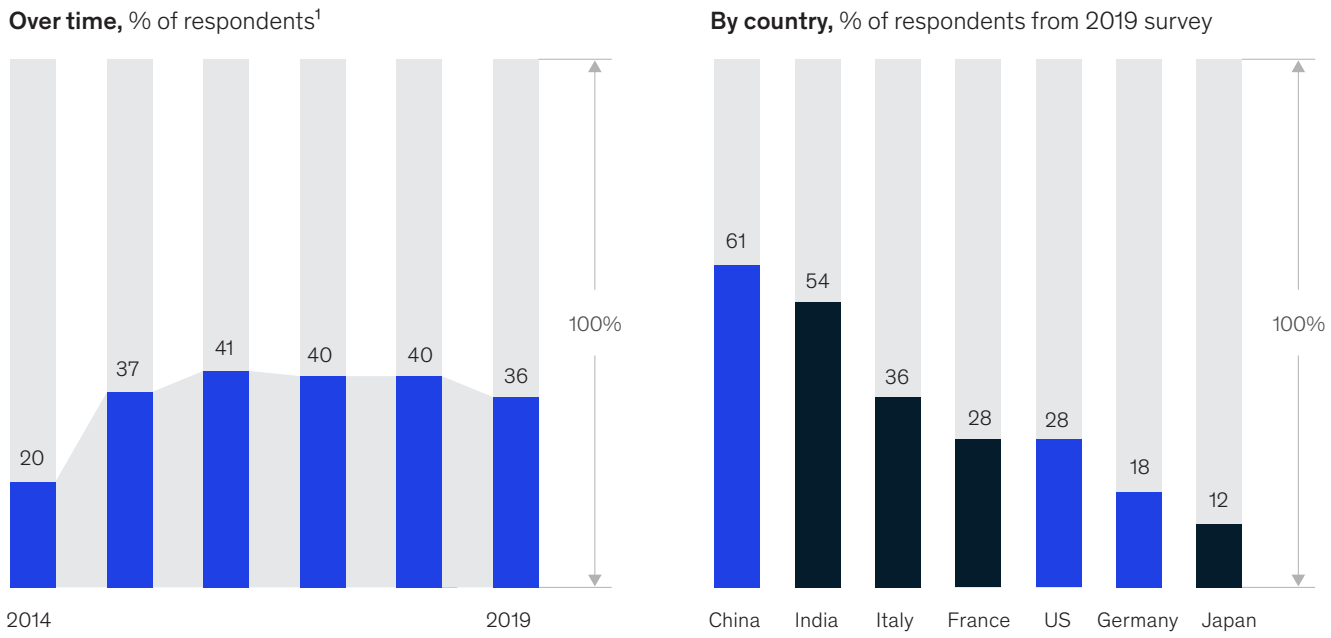
— *Autonomous driving.* Customer perceptions will help established OEMs over the long run, especially in Europe and the United States. For example, 43 percent of German consumers stated that they would prefer to buy an AV from their traditional premium OEMs, which was much higher than the 25 percent who wanted to purchase from companies that specialized in self-driving cars and the 10 percent who wanted to buy from those associated with high-tech giants. The main regional difference can be seen in Japan, where only 6 percent of respondents stated that they trusted specialist self-driving companies but 80 percent trusted traditional OEMs. Americans were half as likely as Chinese or Indian respondents to state that they would trade in their cars for an AV. This finding means that some of the established OEMs, which are currently lagging behind in developing autonomous-driving technology, might have time to catch up and change customer perceptions before AVs become more common. This trust advantage for traditional OEMs is also present in China and India, albeit to a lesser extent.

— *Connectivity.* Consumers in the United States typically prioritize connectivity less than those in Asia. While most Chinese consumers (61 percent) stated that they would switch car brands to achieve better connectivity, only 18 percent of Germans would (Exhibit 2). The number of Americans and French willing to make the switch for better connectivity was also relatively low (28 percent in both markets).

Exhibit 2

The percentage of consumers willing to switch car brands to obtain better connectivity varies by country.

Willingess to change brand to achieve better connectivity



[1] Average of China, Germany, and US, to keep comparability with historical results.

Source: McKinsey ACES Consumer Survey, 2014–19

— *Electric vehicles (EVs).* When Americans contemplate an EV purchase, they are 2.5 times more likely to prefer dealing with a traditional OEM over a specialized EV manufacturer. Ironically, however, many US respondents said the latter lead in developing EVs while established OEMs are losing ground.

— *Shared mobility.* Even if robo-taxis—driverless, on-demand cars—become commonplace and affordable, 70 percent of Germans and 76 percent of Americans want to keep their private cars.

Despite the encouraging survey findings, traditional OEMs still face some headwinds

While consumers believe traditional OEMs have ACES capabilities, they did express some concerns. For instance, our survey found that two-thirds of respondents trusted traditional OEMs—both premium and mass market—to provide vehicles with autonomous features. However, only 43 percent of global respondents stated that traditional OEMs were the leaders in AV development—a drop of 13 percent since 2017. The majority believed that most AV innovation came from "young or rising" car companies or big high-tech players.

Our survey suggests that all automakers, including traditional OEMs, must address consumer concerns about ACES trends. Some customers think that AVs and EVs are too expensive. Others believe that EV range is too limited, or express doubts about abandoning private-vehicle ownership in favor of shared mobility. There are also major questions about the future of ACES in China—the world's largest automotive market and one in which consumers have exceedingly high expectations.

Price pressure for EVs and AVs

Over 70 percent of German respondents believe EVs will lessen transportation's impact on the environment, but fewer than 20 percent would pay a premium for them. This finding also holds true in the global market. For battery electric vehicles (BEVs), only 16 percent of respondents were willing to pay a premium over the price for a vehicle with an internal combustion engine (ICE) (Exhibit 3). Of this group, only 9 percent were willing to pay a premium of 16 percent or more. These findings indicate OEMs may potentially face intense price pressure when bringing BEVs to market.

As with EVs, our survey suggests that AVs may also experience greater price pressure in the future.

Additional electric-vehicle pain points

Beyond price, EVs face other challenges. The top concern relates to vehicle range, even in countries where average driving time is limited. In the United States, for instance, more than one-third of Americans drive fewer than five hours a week, but survey respondents were still worried about range. Charging procedures, including access to charging stations and long charging times, may also deter EV buyers. In consequence, there is a large gap between the number of consumers seriously considering a BEV as their next vehicle and the number with concrete plans to buy one (Exhibit 4). Consider Germany, where about one-third of respondents said they would seriously consider a BEV purchase, but only 5 percent had plans to buy one. The largest discrepancy is found in Japan, where 30 percent of respondents were considering a BEV purchase, but only 10 percent had concrete purchase plans.

Shared mobility

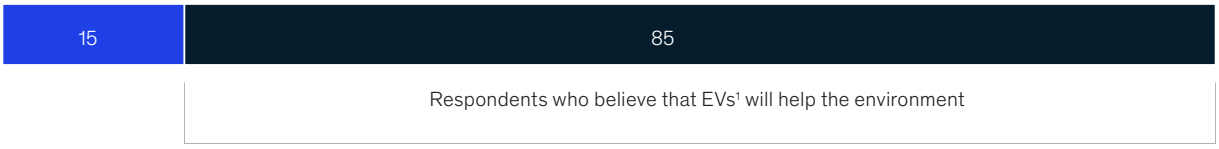
Shared mobility is growing worldwide. For instance, more than 20 percent of German respondents stated that they used car sharing and e-hailing services, which represents a doubling in the past three years.

According to our survey, about 42 percent of consumers would opt for public transportation if shared-mobility solutions were not available, while 2 percent would not take the planned trip (Exhibit 5). These findings suggest that

Exhibit 3

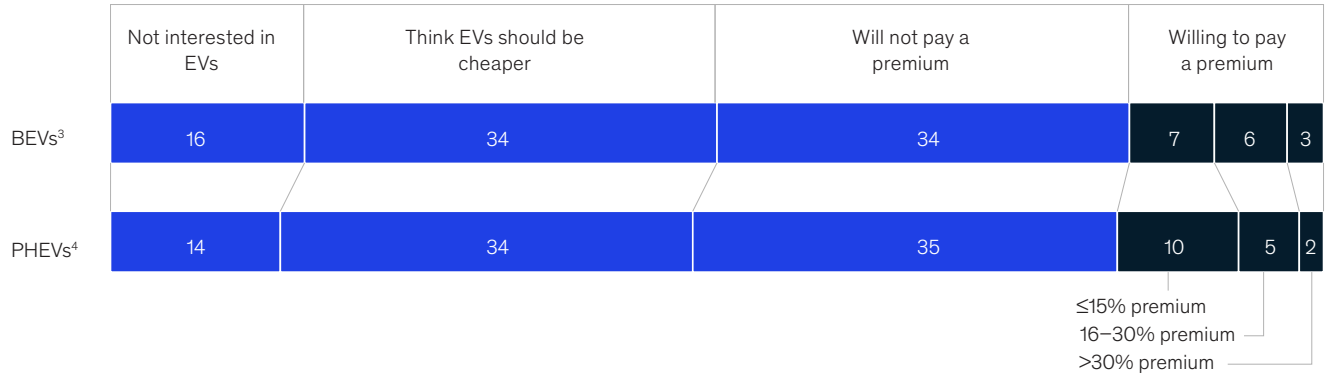
Most consumers know that electric vehicles could help the environment ...

Electrification of vehicles will make a significant difference in reducing environmental impact, % of respondents agreeing



... but are not willing to pay a premium to get one.

Willingness to pay for EVs, relative to vehicles with internal combustion engines,[2] % of respondents



[1] Electric vehicles.
[2] Premium compared with same car with combustion engine.
[3] Battery electric vehicles.
[4] Plug-in hybrid electric vehicles.

Source: McKinsey ACES Consumer Survey, 2019

shared mobility will increase road traffic, since it cannibalizes public transit. That said, it may take years before a significant number of people give up their private cars—the core business for OEMs—and rely entirely on shared-mobility solutions, including autonomous ride-hailing services. Although such services are significantly cheaper than private-car ownership, consumers want to be reassured of a guaranteed pickup—something that may not be possible over the short to medium term.

China

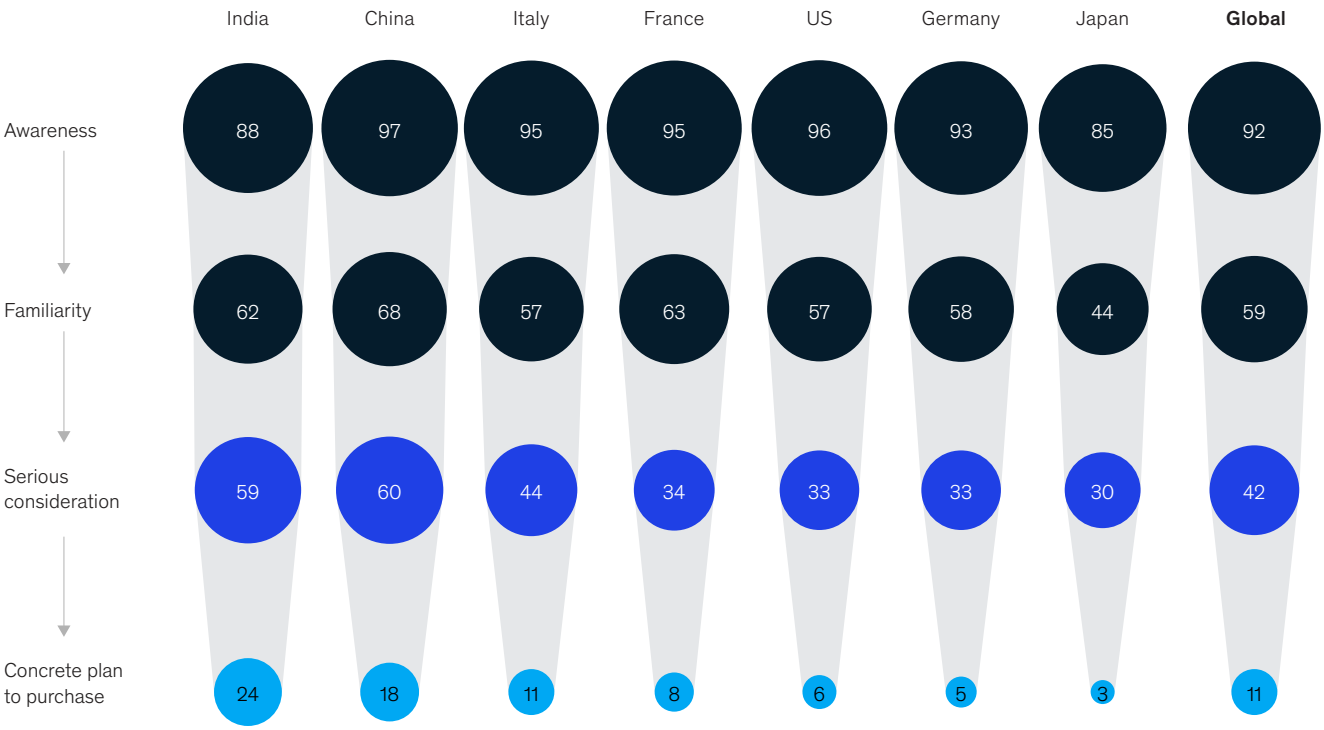
The important Chinese market will not present an easy win for traditional OEMs. Consider some of the most important challenges:

- Data monetization will be difficult. Although 49 percent of Chinese consumers were willing to share their data with big Chinese conglomerates, only 17 percent stated that they would provide this information to their car manufacturers, which are mainly Western.
- As noted earlier, 61 percent of Chinese consumers would switch to a new car brand if it offered better connectivity features.
- Shared mobility may gain traction more rapidly in China. Young Chinese are 20 times more likely to trade in their cars for a chauffeur service today than are those who are over 50 years old.

Exhibit 4

There is a gap between consumers who would seriously consider the purchase of a battery electric vehicle and those with concrete purchase plans.

Stages of purchase for battery electric vehicles,[1] % of respondents



[1]Self-rated in survey.

Source: McKinsey ACES Consumer Survey, 2019

— With EVs, premium and mass-market OEMs are still viewed as the best option for purchase, but they may have difficulty retaining their top position. According to our survey, consumer trust in premium OEMs that sell EVs declined by 25 percent from 2017. Meanwhile, trust in non-automotive technology players that sell EVs increased fivefold.

Exploring other ACES findings

In addition to the findings previously discussed, our survey generated a wealth of other insights on ACES trends. For example, it suggests that OEMs should consider establishing their EV dealership networks in suburban areas, where consumer demand for EVs is highest. Other insights include the following.

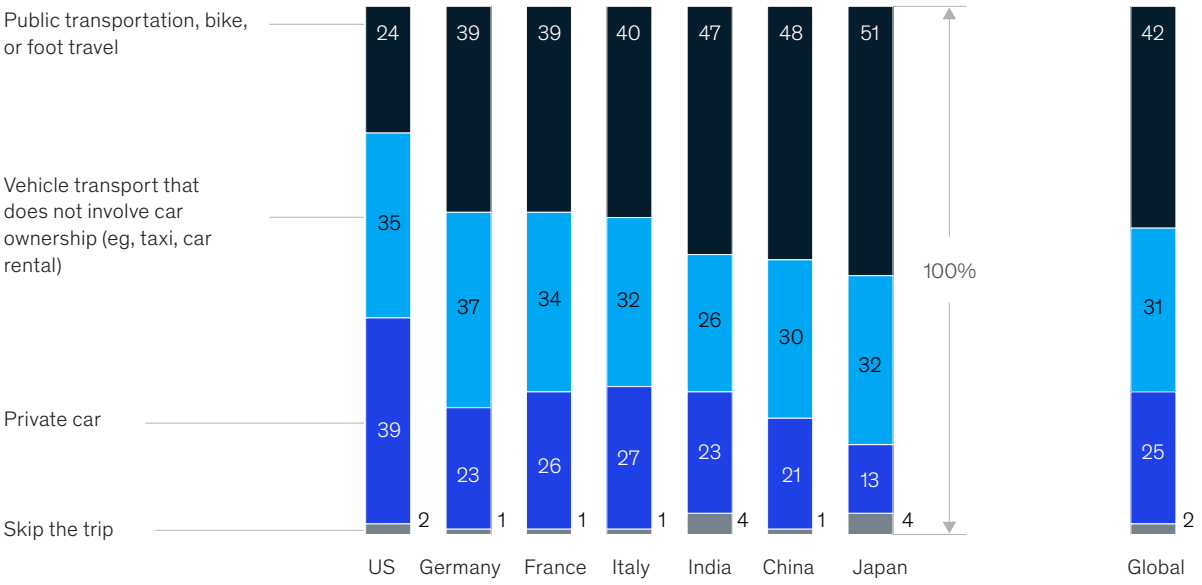
Autonomous driving

Two-thirds of respondents would switch from their current automotive brand to another if it offered better AV driving functionalities. Globally, a third expressed interest in trading in their conventional cars for AVs. In another positive finding, 47 percent said AVs will increase road safety and reduce accidents, while 45 percent trusted OEMs and authorities to make AVs safe. Overall, premium OEMs are losing ground in terms of perceived leadership in autonomous functionalities.

Exhibit 5

If ride-hailing services are not available, most consumers would use public transportation.

Chosen transportation mode when ride hailing is not available, % of respondents



Source: McKinsey Future of Mobility Consumer Survey, 2014–18

Some interesting regional variations emerged about AV attitudes. For instance, 43 percent of consumers in France said they would feel good about family members using fully autonomous cars, as did 46 percent of Italian consumers. In both Germany and the United States, however, only 36 percent of consumers expressed a similar sentiment.

Connectivity

Connectivity features were most important to consumers in China, India, and Italy, in that order. For instance, 93 percent of Chinese respondents stated that gesture control, voice assistance, and emotion recognition was important, as did 88 percent of Indian respondents and 69 percent of Italian respondents.

Electrification

Rural consumers are the most reluctant to pay a premium for EVs. In France, for example, 49 percent of rural survey respondents stated that they were primarily concerned about price when buying a new car, compared with 29 percent of respondents in densely populated cities and 36 percent of respondents in suburban cities. These attitudes could keep EVs concentrated in cities.

Shared mobility

Most respondents in our survey still used either private vehicles or public transportation. In the United States, which has the highest rate of car commuting, 70 percent of respondents stated that they drove to work, suggesting that employers will need to maintain company parking lots for some time.

Our survey clearly indicated that consumers were open to shared mobility, however. Overall, 53 percent of respondents stated that they would be interested in giving up their cars if an autonomous taxi-driving service were available. Respondents from India were most open to shared mobility, with only

22 percent stating that they would keep their car under these circumstances. Globally, only 6 percent of respondents stated that they would move to autonomous taxis and give up their cars if the costs were higher than those associated with vehicle ownership.

As the ACES disruptions continue to transform the automotive industry, players—both established incumbents and new entrants—need to understand and anticipate the evolving competitive landscape. McKinsey's 2019 ACES survey substantiates the growing impact of these trends globally and reveals the changing perceptions of consumers, confirming that these trends are not fads. Western OEMs have been strategically astute in preparing for them.

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Designed by Global Editorial Services

The road ahead for e-mobility

How OEMs can win consumers and achieve mass-market EV adoption

January 2020

by Andreas Tschiesner, Ruth Heuss, Russell Hensley, Ting Wu, Patrick Schaufuss, Patrick Hertzke, Stefan M. Knupfer, and Thomas Gersdorf

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Introduction and key messages

While electrification represents the biggest technological development in automotive power trains in decades, there is still significant uncertainty as to when large-scale adoption of electric vehicles (EVs) will occur. Our working definition of an EV is a light vehicle with an electric power train. The two most relevant segments of EVs – which are the focus of this report – are battery-powered electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).

There is currently a lack of systematic and fact-based investigation of e-mobility industry dynamics which is necessary to understand (i) what is still holding back the mass-market adoption of EVs and (ii) what is required to finally become mainstream.

One thing that is certain is that all car manufacturers have a stake in greater EV adoption, not least because governments are dialing up the pressure to make EVs a more significant share of the mobility landscape. Against this backdrop, this report provides fresh insights – derived from the latest McKinsey research (see Text Box 1) – into four central and pressing questions for the automotive industry at large:

1. What is the current level of mass-market readiness for EV adoption?
2. What are consumers' current perceptions regarding the purchase of EVs – and how have they developed since 2016?
3. How prepared are OEMs and their dealer outlets to sell EVs, and how can their readiness be improved?
4. How can OEMs contribute to rapid, large-scale EV adoption and improve their EV-related business case?

Text Box 1: McKinsey's e-mobility research

— **Consumer preference:** launched a comprehensive consumer survey in 2019 in China, Germany, Norway, and the US of more than 12,000 consumers (for further details, see Text Box 2 on page 9).

— **Sales performance:** carried out a mystery shopping study encompassing 42 visits to the outlets of eight OEMs across three countries (for further details, see Text Box 5 on page 24)

Our research and analyses yielded the following key insights that will be explained in more detail in this report:

1. EV sales are up, and OEMs are planning to release hundreds of new models. Market research shows EV sales approaching 2.3 million vehicles worldwide and a market penetration of 2.5 percent in 2019, while OEMs' EV model pipeline is fuller than ever before with around 400 new, battery-powered electric vehicle models to hit the market between 2020 and 2025
2. More consumers are considering EVs, but not as many are buying. Insights from our EV consumer survey show that consumers' consideration of EVs has increased on average by around 21 percent over the last three years, as consumers have recognized the numerous benefits of EVs. Still, significant EV-specific concerns persist – such as concerns regarding battery/charging, driving range, and higher costs compared to ICE vehicles – and prevent a large-scale consumer pull for EVs
3. There is considerable room for improvement in captivating consumers on EVs. The insights from our mystery shopping study – consolidated in 10 pragmatic recommendations – illustrate how OEMs can improve their sales approach to boost sales and build their EV business case by systematically assessing EV sales readiness
4. Five moments of truth represent make-or-break customer touch points. From our perspective, OEMs need to succeed at five key touchpoints or key consumer interactions, which will trigger a large fraction of consumers to adopt EVs.

1. The stage for EV mass-market adoption is set – almost

EVs have existed for more than a century, but large-scale production and marketing began only a few years ago. Despite this relatively short period of time, the outlook in terms of planned production to be considered, sales, market penetration, and industry dynamics is very positive.

1.1 Global EV sales are approaching a tipping point

EV sales totaled 2.08 million vehicles globally in 2018. After rapid growth between 2016 and 2018 (62 percent p.a.), sales have been increasing more slowly and hit 2.3 million in 2019 (Exhibit 1). However, this development should be considered in relation to the slowdown of the overall light-vehicle market (total light-vehicle market estimated to shrank 4.5 percent in 2019)[1], which, despite a slow down in sales, led to significant growth in EV market share in 2019. The EV market penetration steadily increased from 0.9 percent in 2016 to about 2.5 percent of the total light-vehicle market in 2019 (an increase of 39 percent CAGR p.a.). The fastest-growing market for EVs in 2019 is Europe.

41%

annual growth in market penetration 2016-19

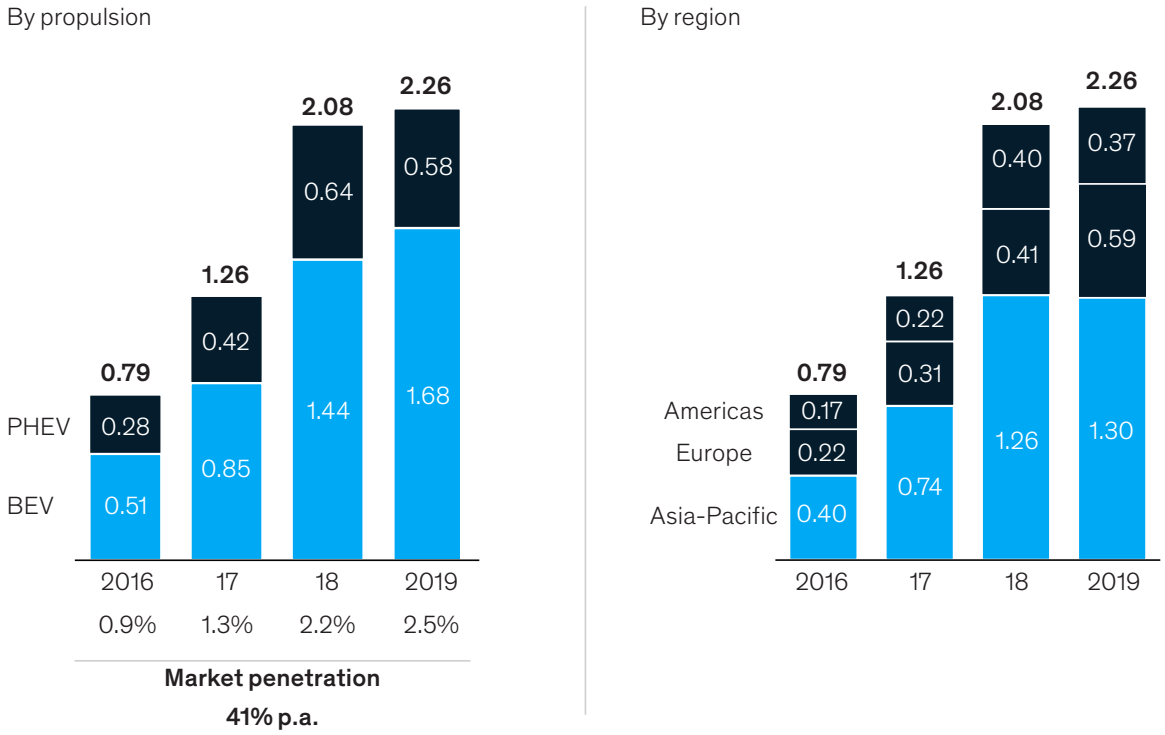
At the same time, there are multiple signs that demand in Europe will pick up even more strongly in 2020. Consumers in several countries are likely to make purchases not before 2020 when higher subsidies are expected (e.g., in Germany). In parallel, CO_2 regulations in the EU will come into effect in 2020, adding strong incentives (on top of existing ones) for OEMs to sell more EVs.

1 Source: IHS Markit (sales forecast as of January 31, 2019), Light Vehicle Sales Forecast (January 31, 2019).

Exhibit 1

Global EV sales and market penetration are continuously growing

Global light electric vehicle sales, 2016-19, million units



Source: EV-volumes.com; IHS Market (sales forecast as of January 31, 2019), McKinsey

1.2 OEM EV model pipeline is stronger than ever before

With around 400 BEV models planned to enter the market by 2025, OEMs and new players have demonstrated their commitment to ramping up EV production and pushing new models into the market (Exhibit 2).

~400

BEV models to be launched by 2020-25

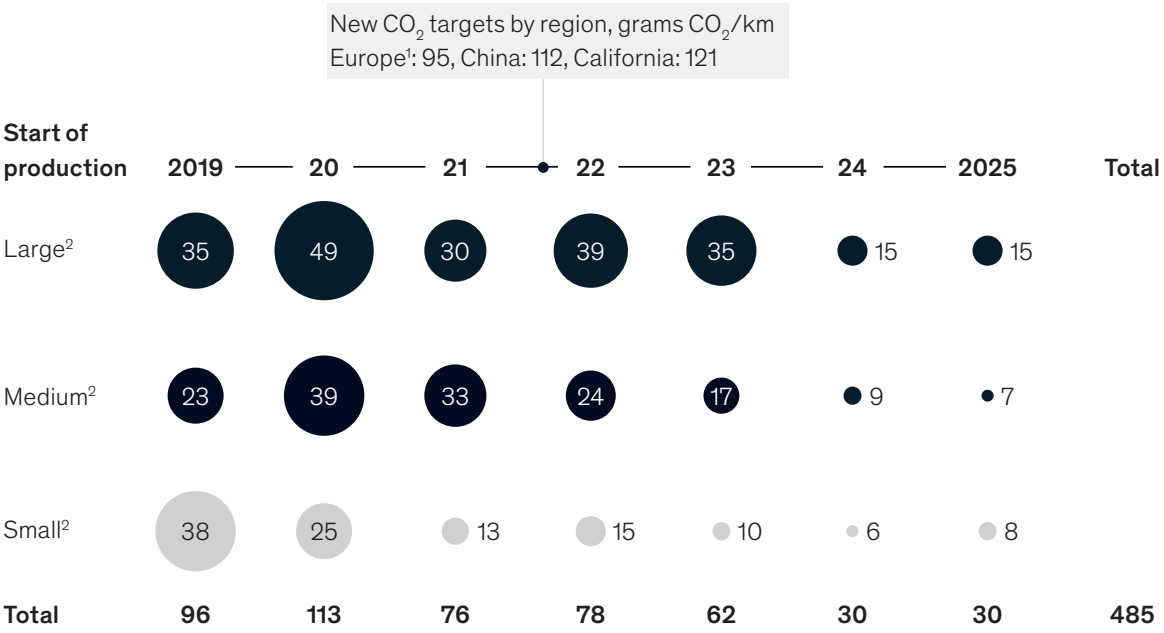
The fact that we see the EV model pipeline fuller than ever before across segments underlines a shift towards mass-market EVs. Enabled by advancing battery technology, larger vehicles with larger batteries and longer ranges are also expected to hit the

market. While before 2017 most BEV models entering the market were small and medium-sized vehicles (e.g., Renault Zoe, Chery QQ, BMW i3, and Nissan Leaf), in 2018 we saw a significant increase in the number of market launches of large EV models (e.g., Jaguar I-Pace, NIO ES8, and Bjev EU5) by OEMs. The number of newly launched larger-footprint BEV models increased from only 7 out of 39 (18 percent) in 2017, to 23 out of 69 (33 percent) in 2018, and 35 out of 96 (36 percent) in 2019. Likewise, the model pipeline until 2025 (see also Exhibit 2) shows a significant increase in the number of BEV models across all major segments.

Exhibit 2

OEMs plan to launch around 400 new BEVs by 2025, with a strong focus on medium-sized and large vehicles

Number of BEV launches



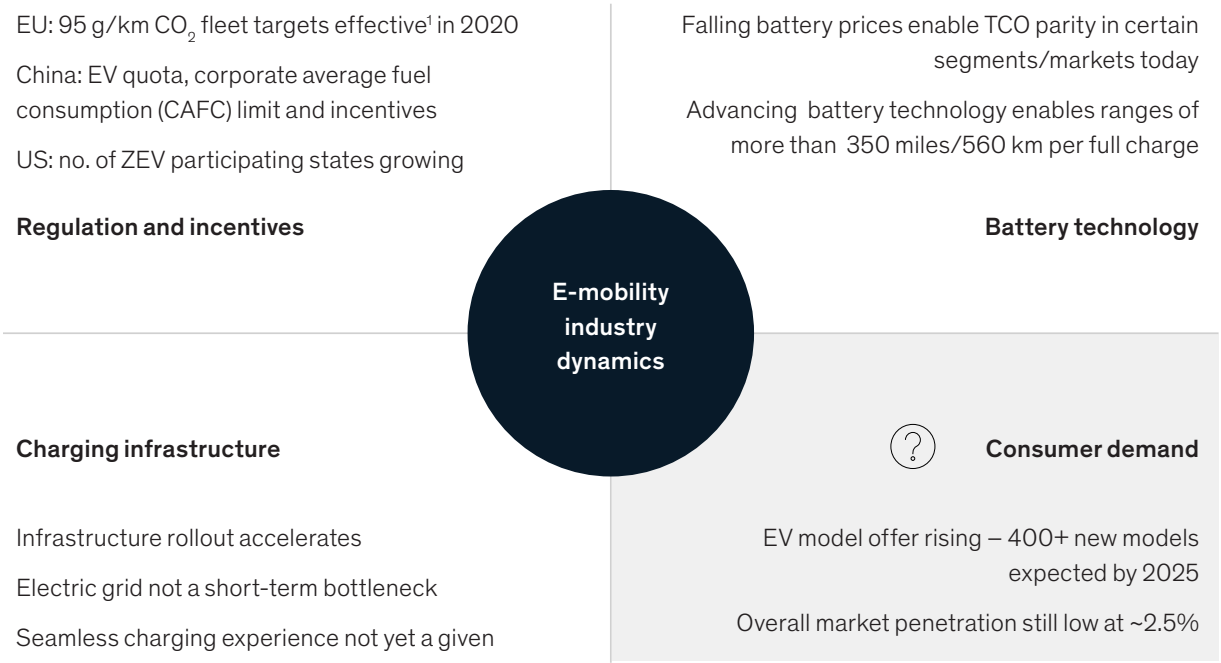
1 Phase in from 2020 for 95% of fleet
2 Small = A/B segment, medium = C segment, large = D/E segment
Source: IHS Markit (alternative propulsion forecast as of November 30, 2019)

1.3 Consumer demand for EVs going forward is the "last big unknown"

Three key dimensions of the EV industry are developing in ways that clearly support greater EV adoption: regulation and incentives, battery technology, and charging infrastructure. However, progress in the fourth key dimension, consumer demand for EVs, is still difficult to predict (Exhibit 3).

Exhibit 3

Consumer demand is the "last big unknown" within e-mobility industry dynamics



1 In 2020, the 95g CO_2/km target only applies to 95% of the fleet
Source: McKinsey

Governments are tightening regulations and offering incentives to foster greater EV adoption

Governments worldwide are imposing increasingly stricter CO_2 regulations. In the EU, for example, a new set of fleet wide CO_2 targets will be phased in starting in 2020. OEMs need to fully comply with an industry wide emission target for CO_2 of 95 grams per km by 2021 to avert significant financial penalties. These mandates are putting additional pressure on OEMs to push EVs into the market. On the consumer side, governments are incentivizing EV adoption. The German federal government, for example, has recently announced its plan to increase its EV purchase price subsidy for BEVs from EUR 4,000 in 2019 to EUR 6,000, starting in 2020 and in effect until 2025.

Non-monetary incentives include an increasing number of cities planning to partially exempt EVs from their congestion reduction policies (i.e., restrictions on vehicles entering the city center). In China alone, on top of the current Tier-1 cities, 10 to 20 additional cities are expected to be under a congestion reduction plan by 2025. Similarly, an increasing number of US federal states (twelve states) have joined California's zero-emission vehicles (ZEV) program, which requires OEMs to sell a steadily increasing share of EVs to be allowed to continue to sell ICE vehicles.

Substantial technological progress has increased the mass-market compatibility of EVs

Several developments in technology are making EVs easier to own. First, decreasing battery prices and large shifts in the power train supply chain are enabling a further reduction in the EV vehicle price. Specifically, EVs in the A and B segment in Europe already have a lower TCO over three years than ICE vehicles. Second, falling battery prices make BEVs the least expensive power train option in terms of total cost of ownership (TCO) in certain segments and markets today. For example, the average list price (before subsidies) of the five least expensive, small BEVs on the Chinese market have decreased by 16 percent to about CNY 86,000 (approximately USD 12,300) over the last three years. Third, advancing battery technology has also led to increases in driving ranges that should make consumers increasingly more comfortable. Specifically, the current top BEV models on the market offer driving ranges of more than 350 miles (560 km) per full charge[3].

Charging infrastructure has been further improved and expanded

Infrastructure rollout is accelerating as several players have started establishing dense charging networks across regions. In Europe, five large OEMs are building a fast-charger network of 400 stations by 2020 under a collaboration called Ionity. In the US, one OEM is investing USD 2 billion over a 10-year period ending in 2027 in both fast-charging stations along high-traffic corridors in 39 US federal states and in public chargers in 17 metropolitan areas. In China, the State Grid Corporation is building 120,000 public charging stations by 2020 and is currently accelerating plans in central and eastern China.

It is still largely unclear how many consumers will actually switch to EVs

Government, technology, and infrastructure developments are clearly conducive to EV proliferation, but consumer concerns about EVs seem to be a sticking point when it comes to large-scale adoption. Consumers commonly ask several critical questions about EV technology that describe their concerns:

— Will the battery capacity provide the driving range that I need?

— How will I charge my EV if I am unable to install a charging outlet at home?

3 EPA standard

— If I buy an EV today, will the technology be outdated tomorrow?

— How long do EV batteries last and provide their full capacity?

— How does the value of my EV depreciate over time?

Until these questions are convincingly answered, the EV stage will remain set but with a critical mass of potential EV drivers waiting in the wings. To lay the foundation for a potential breakthrough, the following chapter examines what OEMs can and should do to captivate consumers.

2. Understanding the preferences of consumers is key

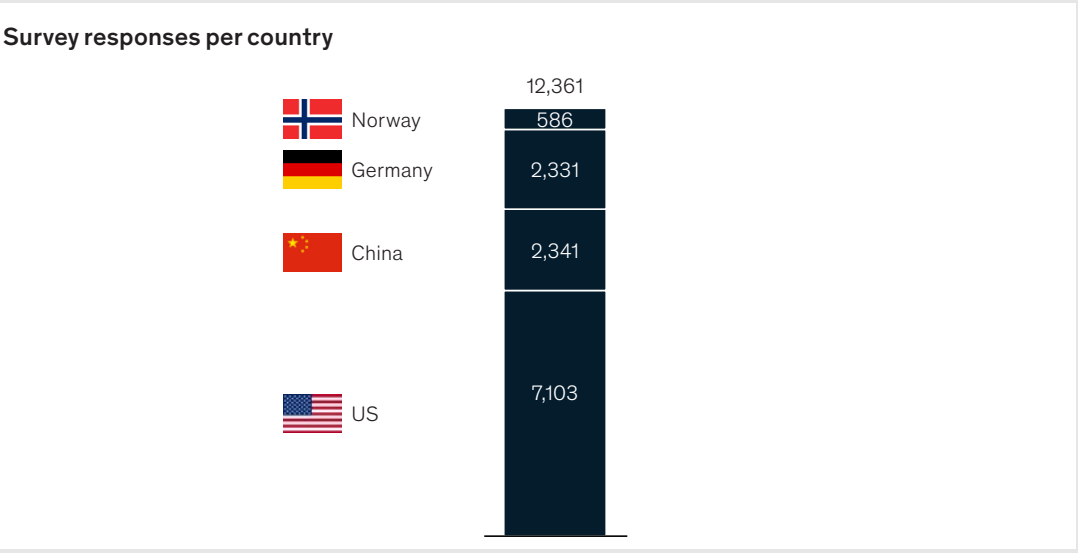
The results of the McKinsey EV Consumer Survey 2019 (see Text Box 2) reveal an interesting mix: significant improvement in consumer consideration rates and user satisfaction of early adopters on the one hand and persistent concerns and lack of information of most vehicle consumers on the other. These key insights and several additional findings from the survey results show how understanding current consumer perspectives on EVs and the development of those perspectives over the past three years are key to improving the consumer EV sales experience and increasing EV sales.

Text Box 2: the McKinsey EV Consumer Survey 2019

- Over **100** questions for general consumers and EV owners about their car usage habits, perceived benefits, and concerns about EVs, and preferences on the car-purchasing process and services
- **Four** key EV markets on **three** continents (Exhibit 4)
- Over **11,100** survey responses from consumers and more than **1,200** responses from EV owners (separate panel compiled by over-sampling EV owners without selection bias)
- **Comparison** to the McKinsey EV Consumer Survey 2016 to identify trends

Exhibit 4

4 key markets covered by the EV consumer survey



Source: McKinsey EV Consumer Survey 2019

2.1 EV consideration has increased, yet EV sales conversion remains low

Regarding consumer attitudes and behaviors related to the EV sales funnel, we have derived a clear range of insights from product awareness on one end to product purchase on the other (Exhibit 5).

Unchanged near-universal awareness. Almost all consumers know of the existence of EVs. Today's level of awareness is above 90 percent in all key markets and is largely unchanged since our 2016 survey. Consumer awareness in China is highest at 99 percent.

Moderate changes to familiarity and knowledge of technology/model availability. The share of consumers familiar with the "tech basics" of EVs is around 43-47 percent. Regionally, this ranges from 43 percent in the US to 74 percent in China. This represents a slight decline over the share reflected in our 2016 survey, but it does not necessarily suggest a drop in consumers' general EV-related knowledge. Many new models have hit the market in the last three years, and there were simply more technical details and different features for the customers to be familiar with in 2019 than there were in 2016.

Purchase consideration has strongly increased since 2016. Among those with a basic knowledge of EVs, there has been significant growth in the number that would consider purchasing one. While only 29 to 44 percent of consumers outside China reported a willingness to consider purchasing an EV in 2016, 36 to 51 percent in 2019 said they would, and this applies fairly equally to both PHEVs and BEVs. The regional difference is quite stark, with the lowest level of consideration observed among US consumers (though the three-year increase of about one-fourth is strongest here). Consumers in China are most likely to consider an EV purchase (80 percent of those with an understanding of EVs). For further details about the EV consumer in China and the US, see Text Box and Infographics 3 and 4 on page 15-17 and 21-23.

Completed purchases[4] remain low. Overall, a very small percentage of consumers are present in the purchase stage of the EV sale funnel[5]. The biggest share of consumers represented in the purchase phase in 2019 was in Norway at 44 percent, up from 24 percent in 2016. All other regions show only a single-digit market share, with China being second at 5 percent. We are observing modest increases, but the percentage of car buyers choosing an EV (BEV or PHEV) remains in the single digits outside Norway.

Given these developments, what are the reasons behind the increase in EV consideration but the persistently low EV purchase rates?

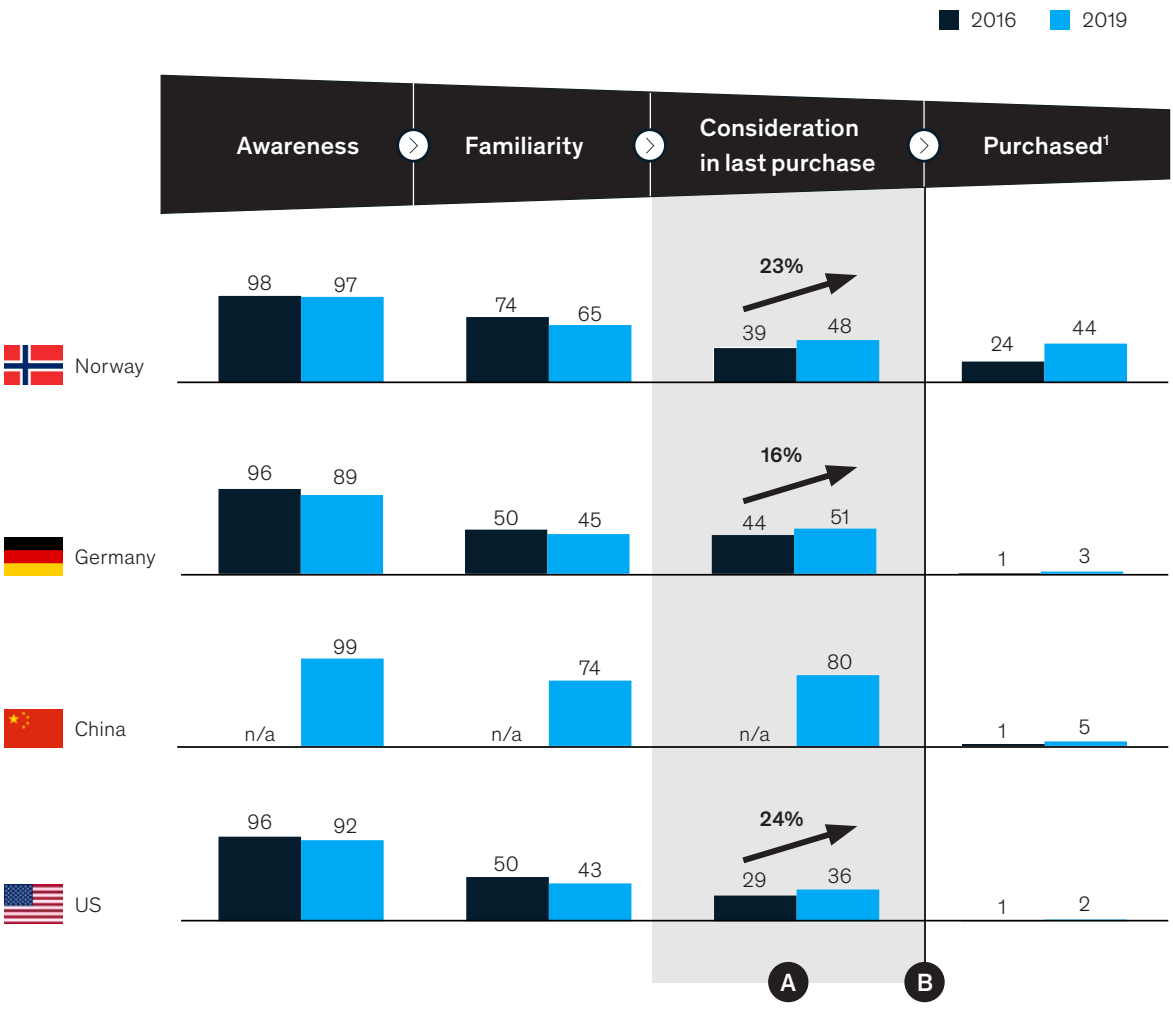
4 EV market share calculated using figures from Q1-Q3/2019

5 To yield insights into the perspective of current EV owners, we ran an additional sampling strategy to increase the number of EV owners in our sample This over-sampling strategy is free of selection bias and has been analyzed separately from the representative sample of the population in the key markets

Exhibit 5

While an increasing share of consumers are considering EVs, conversion into actual EV purchases remains low

Percentage of consumers at each funnel stage for PHEVs and BEVs
(self-rated in survey; actual sales figures for "purchased")



Key observations

A EV consideration up ~21% over the last 3 years (average of Norway, Germany, and China)

B Conversion into purchases remains low due to unresolved concerns

1 Actual sales figures, market penetration of BEV/PHEV in percent
Source: McKinsey EV Consumer Survey 2016 and 2019; EV-volumes.com; IHS Markit (sales forecast as of November 30, 2019), McKinsey

2.2 Perceived benefits of EVs are still outweighed by perceived concerns

Increasing awareness of EV benefits explains increasing consideration

As more and more EV models hit the roads, more consumers are becoming aware of the benefits. Word of mouth is a powerful force, as more people know someone (or know someone who knows someone) who owns an EV.

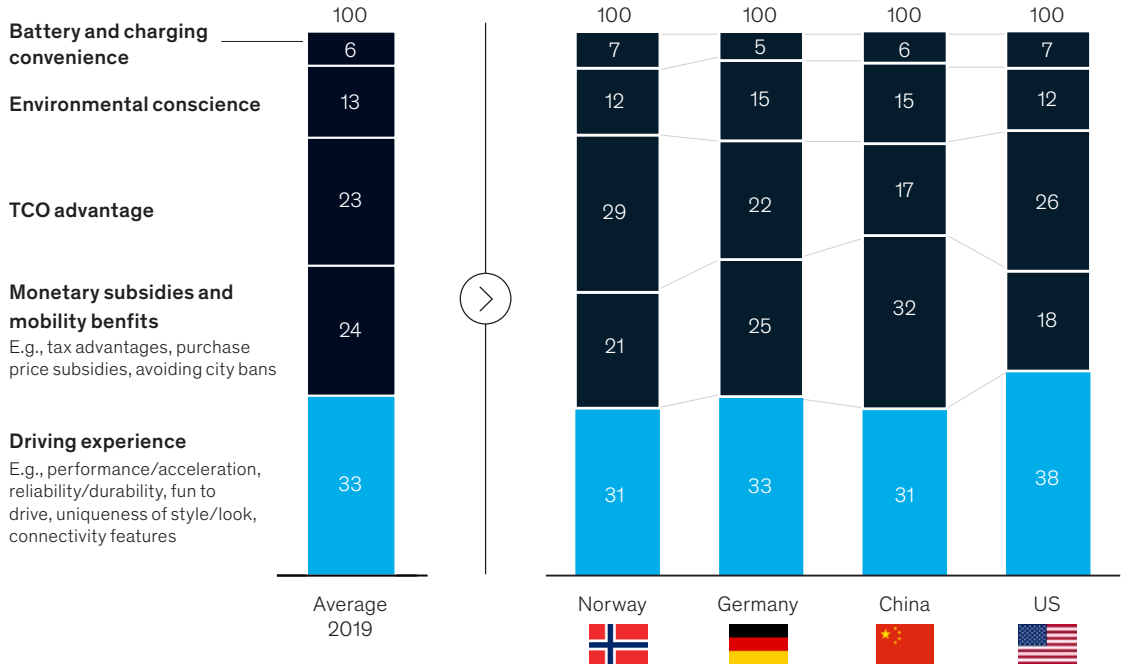
Of all the perceived EV benefits, the driving experience stands out as the most popular – being included in about one-third of consumer responses (Exhibit 6). Consumers appreciate the almost-silent driving experience paired with high acceleration rates (high-end EVs accelerate from 0 to 100 km per hour (62 miles per hour) in less than three seconds).

Exhibit 6

The EV driving experience stands out from the multiple benefits of EVs that consumers are aware of

A. Increasing consideration

Benefits perceived by consumers who considered EVs in their last purchase
Average of PHEV owner and BEV owner perspectives, N(PHEV)=2,616; N(BEV)=2,551; average share of responses per category, percent



Source: McKinsey EV Consumer Survey 2019

Another benefit perceived by a growing number of consumers relates to cost advantages. Specifically, about half of the benefits mentioned by consumers considering EVs relate to TCO or subsidies. The government provision of direct and indirect subsidies reaching up to 40 percent of the vehicle purchase price is reflected in consumers' stated perception. This benefit is most clearly articulated by consumers in China – a country where both local and federal governments are currently strongly incentivizing EVs (see Text Box and Infographics 3 on page 15).

Although the environmental advantage of EVs is frequently discussed in the media – BEVs have zero local emissions and up to 50 percent better lifecycle CO_2 footprints than ICE vehicles today – it is only the fourth most popular benefit for consumers.

The convenience of charging the EV battery at home is also listed among the benefits and – although mentioned by only 6 percent of consumers – contrasts with our observation that consumers mentioned several topics related to batteries and charging as concerns. Apparently, the fact that EVs are battery powered and need to be charged with specific chargers is a significant concern to many consumers who have yet to commit to purchasing an EV. However, some consumers already perceive it as a benefit (e.g., because it eliminates the need to stop at a gas station, as EVs can be charged at home).

The growing awareness of these benefits is the most reasonable explanation for the fact that, nowadays, more consumers than before reach the consideration phase of the EV purchase funnel.

Persistent concerns prevent many customers from purchasing an EV

Although the increasing awareness of the benefits is bringing consumers to the consideration stage of the EV purchase funnel, EV-related concerns appear to be a blockage in the funnel, keeping consumers in that stage and the purchase level consequently still low.

This holds especially true as concerns related to battery/charging have deepened over the last three years, such that battery/charging and driving range represent more than half of all concerns mentioned by consumers considering EVs (Exhibit 7). In detail, battery/charging issues make up 38 percent of all reported concerns, up from 13 percent in 2016. The anxiety around driving range discussed earlier persists, but it has remained stable over the last three years, at 16 percent.

This concern, however, is largely unfounded. Most consumers drive a much shorter distance per day than the total range allowed on a fully charged BEV. Modern EVs can deliver a "real world" driving range of 200 to 500 km, meaning that a fully charged battery can last for several days of average driving. For example, all models across segments on the German market in 2019 provide driving ranges of 200 km, and four out of 18 models provide driving ranges greater than 500 km.

Even if consumers drive long distances (e.g., while going on vacation), they take regular breaks that can be used to charge the vehicle using fast chargers. In Germany, for example, 74 percent of the respondents in a representative survey[6] indicated that they take a break within the first four hours of driving.

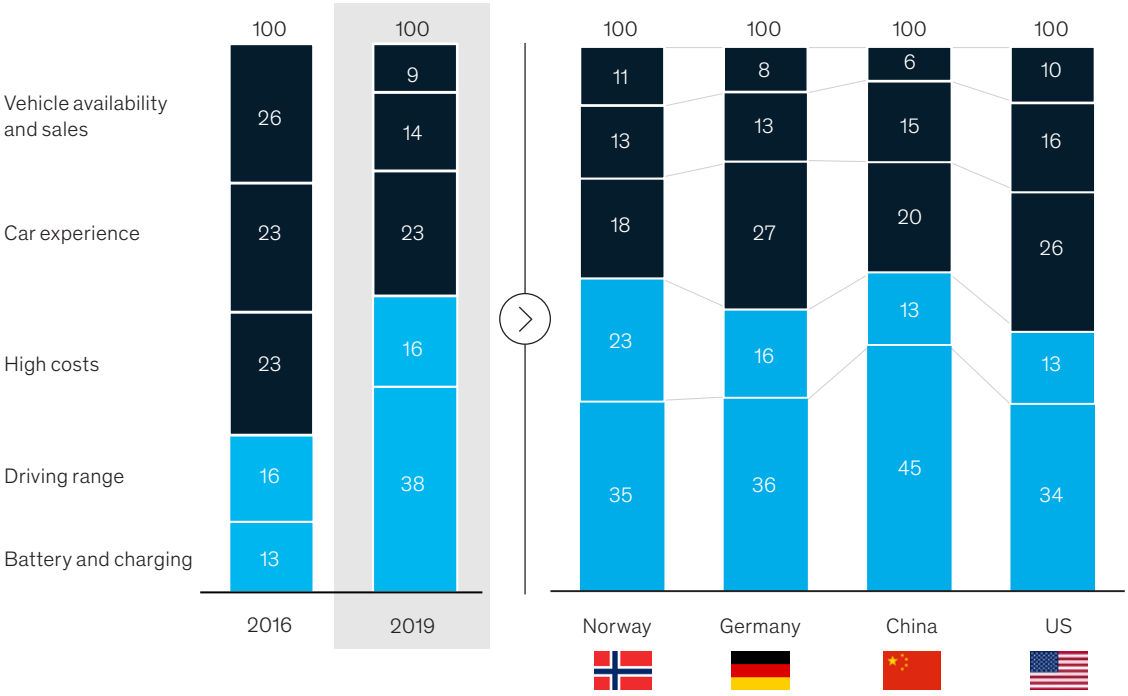
6 TNS Emnid survey sent out in 2016 with results representing 1,000 car owners in Germany

Exhibit 7

Concerns related to battery, charging, and driving range have grown over the last 3 years

B. Low conversion to purchase

Concerns perceived by consumers who considered EVs in their last purchase
Average of PHEV owner and BEV owner perspectives; N(PHEV)=2,616; N(BEV)=2,551; average share of responses per category, percent



Source : McKinsey EV Consumer Survey 2016 and 2019

Three years ago, vehicle availability was the most prominent concern; today, it is the least, dropping from 26 percent to only 9 percent. Meanwhile, the number of BEVs on the market has grown four fold, a reality that consumers have clearly observed. To capitalize on the momentum of consumers' increasing consideration of EVs, OEMs will need to address the persistent (and, in some cases, deepening) concerns that keep conversion rates low.

Text Box and Infographics 3: deep dive on consumer insights in China

EV consideration in China: high across the board and still rising

About 80 percent of consumers in China considered an EV when making their most recent vehicle purchase, and variation by age and region was relatively low, i.e., 67 to 85 percent (Exhibit 8). The share of consumers who considered an EV purchase was only slightly higher both in larger cities and among younger segments.

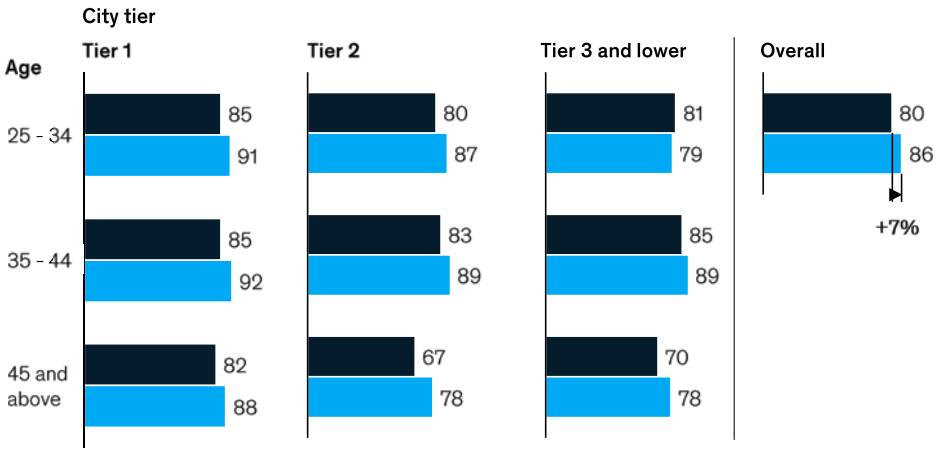
Looking ahead, across all city tiers and age segments, even larger shares of consumers expect to consider EVs, with an overall average of 86 percent of consumers stating that they will consider an EV when making their next vehicle purchase. The biggest jump from "last purchase" to "next purchase" is observed in the segment of Tier-2 city consumers age 45 and older, who represent an uptick in consideration of 11 percentage points (from 67 to 78 percent).

Exhibit 8

Consideration of an electric vehicle is consistently high around 80%, and increasing further

Consideration of EVs consumers' last year and next car purchase[1]

Percent of consumers, PHEVs and BEVs



1 Last purchase, on average, 18 months ago; next purchase expected in, on average, 16 months
Source: McKinsey EV Consumer Survey 2019

EV penetration: slower growth rate and shift to mid-class vehicles

EV sales and market penetration in China have almost doubled from 2018 to the first half of 2019 (Exhibit 9), making China the fastest-growing market with the four key markets studied. In this timeframe, market penetration increased from 3.2 to 5.8 percent. However, given that governments in China are continuing to reduce the financial subsidies – purchase price subsidies have been decreasing every year since 2014 – EV sales will continue to increase, but most likely at a lower rate.

Most EV sales in China are still small vehicles in the A-class segment and below (e.g., the model BYD E5 in the A-class or model Baojun E100/E200 in the below-A-class segment).

Additional growth in 2019 has come mainly from vehicles in the A, B and C class. Furthermore, the share of entry level, below-A-class vehicles has decreased from 53 to 35 percent and is expected to decrease further. A driving factor may be related to the reduction in monetary subsidies mentioned above, because they represent a bigger discount for smaller vehicles, given how large the subsidies are, relative to the lower purchase price.

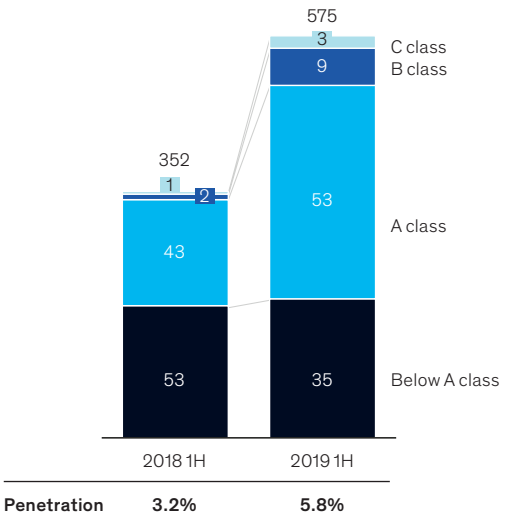
As both the federal and local governments are increasing non-monetary incentives, such as privileges for EVs in city centers, customers in other car segments are also switching for non-financial reasons. At the same time, foreign premium brands are introducing additional EVs to the market, which has so far been dominated by domestic manufacturers of small cars. However, it is still unclear whether the EV market growth in China is sustainable without significant financial incentives. Given the advanced stage and size of the EV market, the developments in China will provide early indications of developments of the EV mass market.

Exhibit 9

Market penetration has increased significantly due to growth from A- and B-class vehicles

Sales breakdown of EVs

PHEV and BEV sales in first half of each year in 1000 units, percent



Source: 2019 McKinsey China Auto Consumer Report; CPCA

The public charging network has grown rapidly

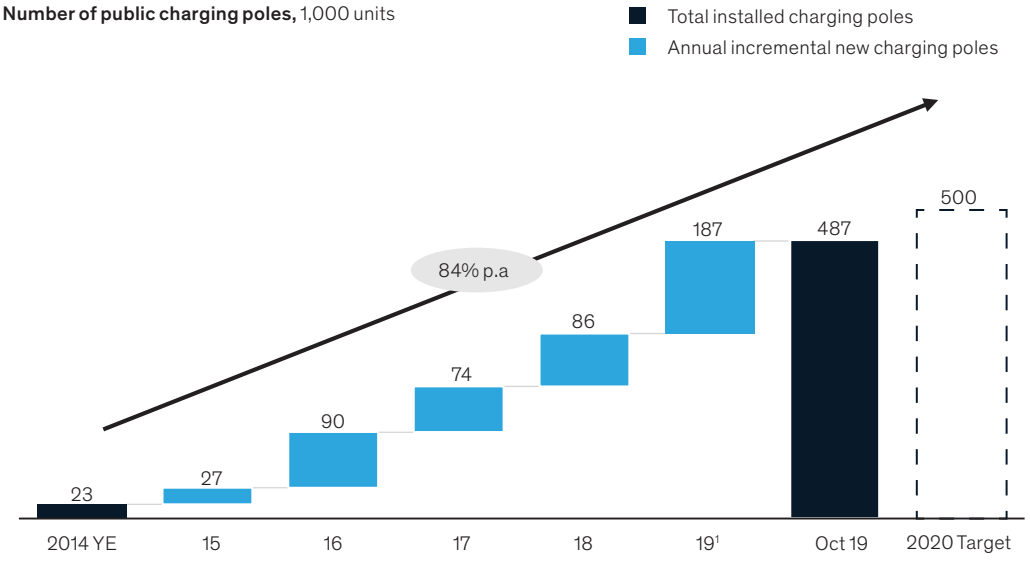
China has the largest installed base of charging equipment (mostly located in its eastern states with big cities). Still, insufficient availability of public chargers is the biggest concern among Chinese consumers, with 50 percent naming it among the top reasons why they would not consider purchasing a BEV. Closely related to this concern is the fact that 26 percent of consumers think BEVs should have driving ranges of more than 500 km per charge.

The federal government aims to have 500,000 public charging stations installed by the end of 2020. In the last few years, the number of installations grew rapidly at 84 percent p.a. and reached 487,000 by October 2019. However, the public charging service still face challenges: EV owners have sometimes found public charging stations not working or blocked by other (ICE) vehicles. At the same time, charging infrastructure operators are concerned about a profit-losing utilization rate as low as 10%.

In addition, there is progress regarding the availability of semi-public and private charging stations. The New Energy Vehicle Development Masterplan 2021-2035 (draft) encourages the use of shared charging stations within gated residential communities as well as smart-charging facilities at commercial sites. In July 2019, the largest real estate developers in China partnered with the State Grid Corporation of China to drive smart charging service at their real estate properties.

Exhibit 10

The public charging network has grown rapidly during past few years



1 Jan - Oct 2019
Source: EVCIPA (December 2018)

2.3 Today's BEV buyers are a lot different from ICE vehicle buyers

One key to boosting BEV adoption may be developing an understanding of the stark differences between today's BEV and ICE-vehicle buyers. Our research has shown key differences in several areas related to demographics, attitudes, and perceptions. BEV owners differ from their ICE vehicle-buying counterparts within the following five key demographic characteristics (Exhibit 11).

Specifically, BEV owners:

— Are on average five years younger

— Are more likely to live in urban areas

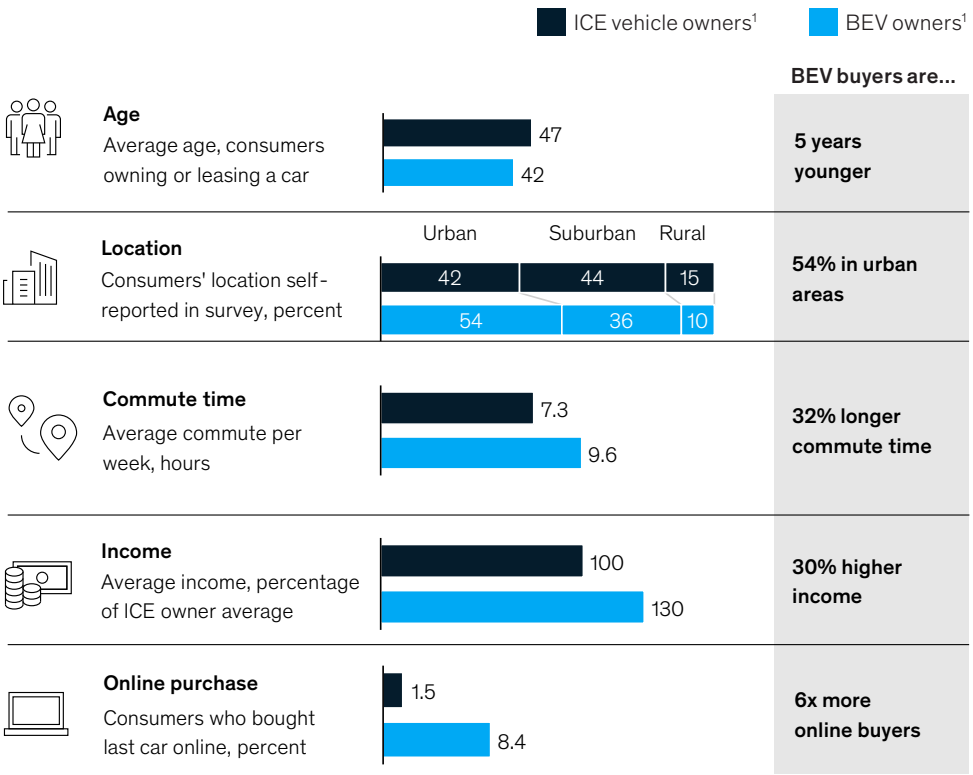
— Have a 32 percent longer commute time

— Earn 30 percent more

— Are six times more likely to have bought their last car online

Exhibit 11

5 key characteristics distinguish EV owners from ICE vehicle owners



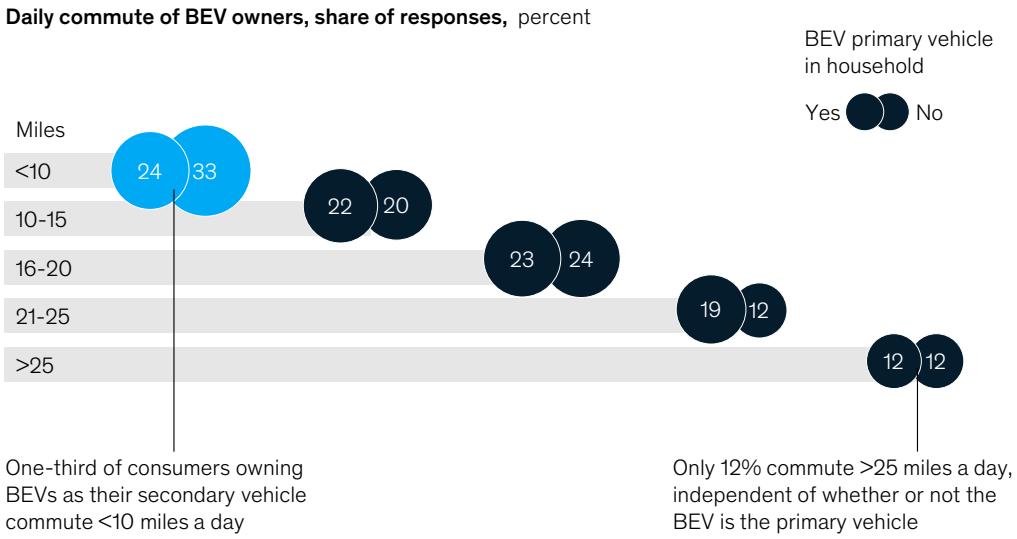
1 Average of China, Germany, Norway, and the US
Source: McKinsey EV Consumer Survey 2019

The early adopters of BEVs appear to be a specific fraction of consumers who can be described as tech-savvy, urban consumers with above-average incomes, and who are much more accustomed to online shopping.

Current BEV owners have a broad range of commute times, but a significant share of them travel less than 10 miles per day: 24 percent of BEV owners for whom the BEV is the primary household vehicle and 33 percent for whom the BEV is not the primary vehicle (Exhibit 12). Only 12 percent of BEV owners have a daily commute of more than 25 miles.

Exhibit 12

Current BEV owners drive mostly short distances, no matter whether they use their BEV as a primary or secondary vehicle



Source: McKinsey EV Consumer Survey 2019

Looking at attitudes and perceptions, BEV owners describe the driving experience as the primary benefit of BEV ownership. Specifically, one third of all benefits perceived by BEV owners relate to the EV driving experience – up from one fifth three years ago. Revealingly, EV owners mention the appeal of the EV driving experience with the same frequency and experience as consumers in the EV consideration stage, suggesting that expectations become fulfilled once consumers buy and experience EVs.

Early adopters are also more likely to find ways to adapt to the new battery and charging technology, because they mention it slightly more often as a benefit (8 percent instead of 6 percent, Exhibit 13) and slightly less often as a concern (35 percent instead of 38 percent). However, battery-and charging-related concerns are still, by far, the most frequently mentioned concerns.

Given that EV performance is improving and exceeding consumer expectations – nine out of ten EV owners would consider purchasing an EV again – a key task for OEMs and their dealer outlets is to convince the average consumer of the benefits of EVs and to alleviate any remaining concerns about EVs. Today's typical EV buyers live in cities and buy EVs because they only travel short distances, so range anxiety is not a key concern. Another motivating factor in their EV purchase – at least in some markets – is that larger cities are increasingly restricting ICE vehicles in city centers. To expand EV adoption beyond the urban, tech-savvy consumers who are easily accustomed to EVs, OEMs will need to adapt their sales approach so that it teaches and convinces other consumers who commute longer distances, are older or not as tech-savvy, or have significant concerns regarding whether an EV can actually fulfill their mobility needs.

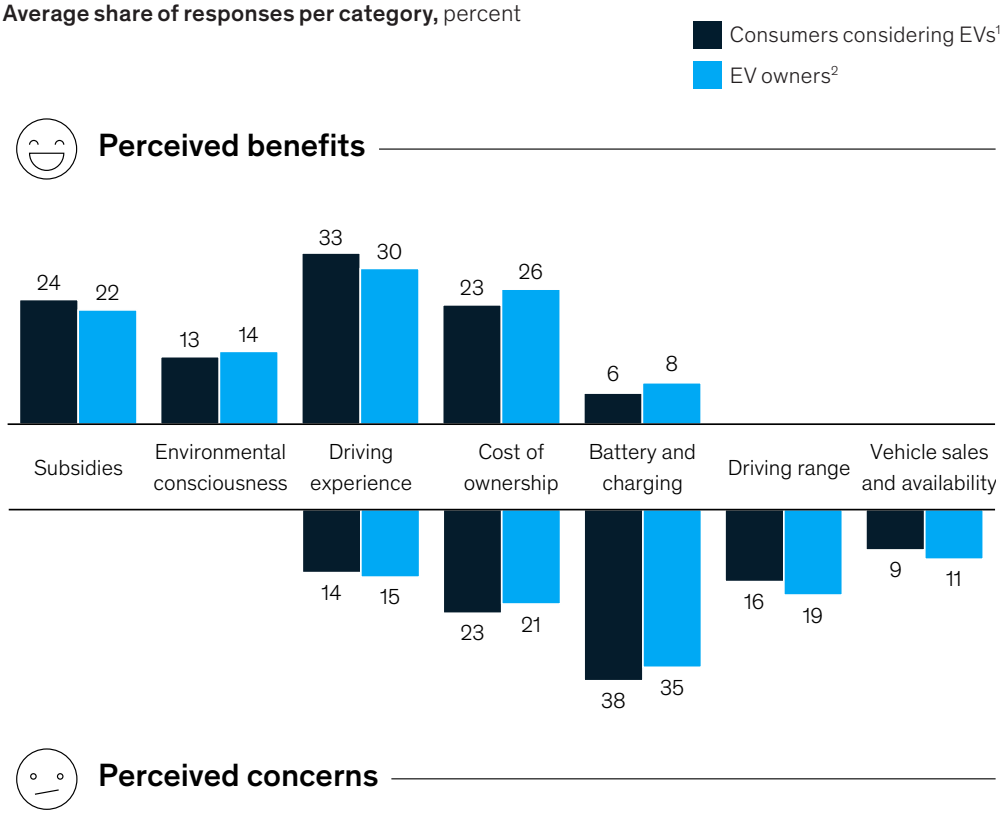
91%

of EV owners would choose an EV again in their next purchase

Exhibit 13

Benefits and concerns perceived by EV considerers and EV owners

Average share of responses per category, percent



1 Average of consumers considering BEVs and consumers considering PHEVs
2 Average of BEV and PHEV owners
Source: McKinsey EV Consumer Survey 2019

Text Box and Infographics 4: deep dive on consumer insights in the US

EV consideration in the US: low on average but highly variable and growing

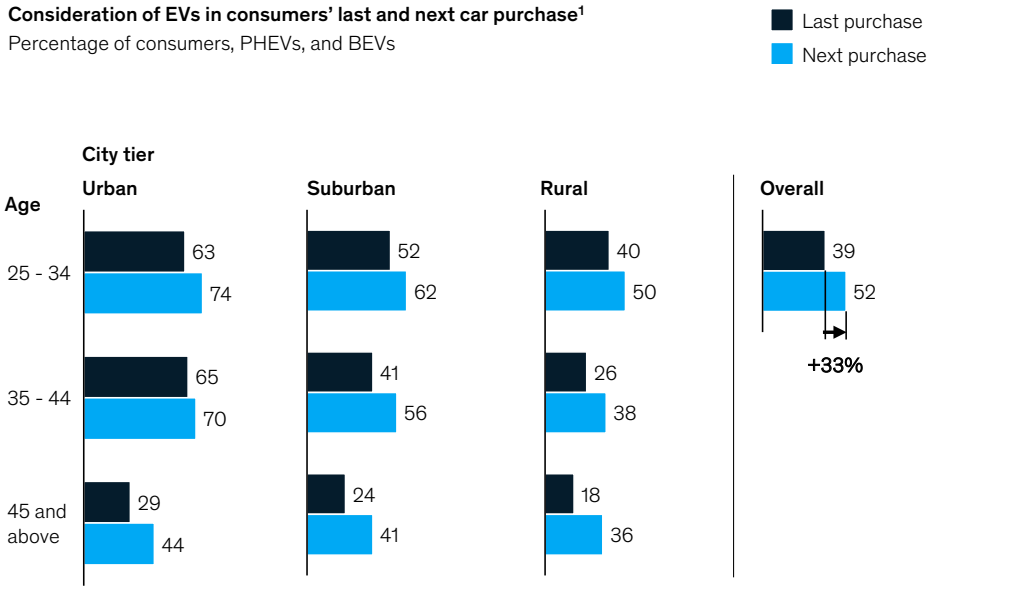
When making their most recent vehicle purchase, around 39 percent of consumers in the US considered an EV, the lowest rate among the four key markets in the study (Exhibit 14). This average, however, masks a large spread and significant differences across consumer groups. Specifically, younger consumers in urban areas are the most represented among those who considered an EV (approximately 65 percent), while older consumers in rural areas were least represented (18 percent).

Regarding their next vehicle purchase, now, 52 percent of US consumers expect they will consider an EV, which represents a 33 percent increase over the share who considered EVs in their most recent vehicle purchase. Overall, the increase can be observed across all consumer segments, city tiers, and age groups, but it is the segment that considered EV the least (older, rural consumers) who represents the biggest jump from "last car" to "next car" (a 100 percent increase). OEMs should gear their go-to-market approach to such consumers.

Exhibit 14

Consideration of an EV is consistently higher with younger, more urban populations

Consideration of EVs in consumers' last and next car purchase[1]
Percentage of consumers, PHEVs, and BEVs



1 Last purchase, on average, 19 months ago, next purchase expected in, on average, 19 months
Source: McKinsey EV Consumer Survey 2019

EV penetration: very low but growing

The total annual EV market size in the US is around 310,000 vehicles (2019, BEVs and PHEVs), which is slightly less than one-fourth of the annual Chinese market (about 1.2 million EVs). Market penetration of BEVs in the US rose to 1.3 percent in the first half of 2019 and is increasing steadily.

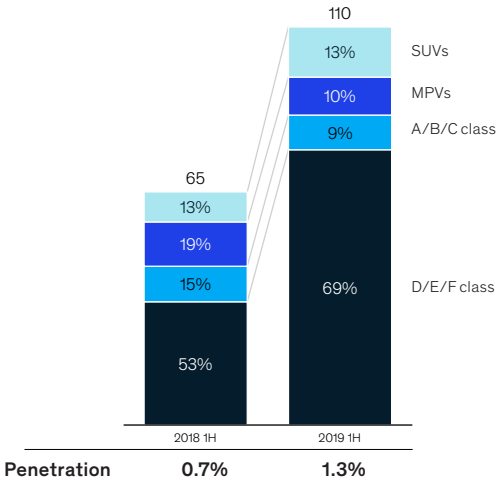
Growth comes mainly from large vehicles in the D/E/F class segments, which is in stark contrast to China's A- class and below-A- class segment growth. Specifically, 70 percent of all BEV sales in the US in the first half of 2019 were D-/E-/F-segment cars.

Exhibit 15

Growth in BEV sales mainly from large cars in the D/E/F class segment

US

Sales breakdown of BEVs, first half of each year, 1,000 units



Source: IHS Markit (sales forecast as of November 30, 2019)

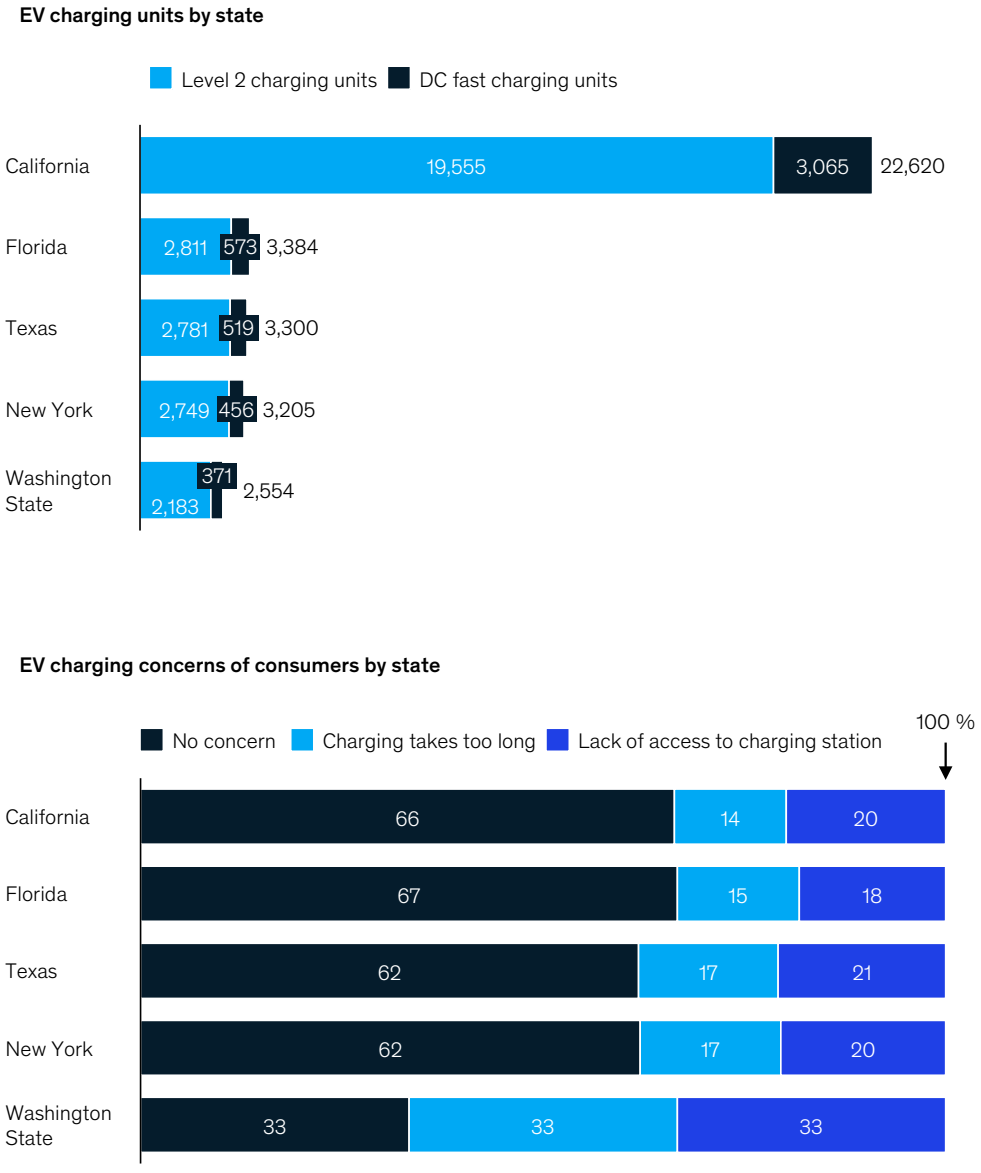
Charging is a key concern – even in the state with the densest charging network

As in other regions, battery/charging and driving range are the most important concerns among US consumers (approximately 47 percent of consumer responses about their expressed concerns related to battery/charging and driving range). More specifically, the main concerns in the US are the speed of charging and the availability of public charging stations.

The distribution of the charging network in the US is very uneven. California, by far, has the most public charging poles of all states in the US. Even when accounting for size or population, the charging network in California is the densest. However, consumers in California are just as concerned about access to charging stations (around 20 percent) as the consumers in states with just a fraction of California's charging network.

Exhibit 16

California has, by far, the densest charging network; yet consumers are no less concerned about ease of charging



Source: Elektrek Analysis (July 2019); McKinsey EV Consumer Survey 2019

3. Measuring consumer car-buying experiences sheds light on OEM EV sales readiness

As the results of the current EV Consumer Survey in Chapter 2 show, consumer attitudes about EVs have improved significantly since 2016. OEMs should thus make systematic efforts to affirm consumers' growing positive attitudes towards many aspects of EVs (such as the driving experience and subsidies), disprove their concerns that do not reflect reality (such as range anxiety), and solve pressing pragmatic problems (such as the availability of charging stations), which might differ regionally.

To help OEMs as well as their affiliated dealer outlets optimize EV sales readiness, we developed a six-dimensional measurement instrument (Exhibit 17) and conducted a mystery shopping exercise at the dealer outlets of some major OEMs to analyze their EV sales readiness in detail. The results pinpoint the areas where dealers can improve their sales process to align with their most successful competitors and positively impact the attitudes of EV customers (see Text Box 5).

Text Box 5: the McKinsey EV Mystery Shopping Survey 2019

This survey employed incognito store visits to assess the six measurable dimensions of the EV sales readiness framework. The survey approach comprised:

- **Eight** OEMs
- **42** store visits in **three** metropolitan areas in **three** key markets (Los Angeles, Düsseldorf/ Cologne, Shanghai)
- **Six** EV sales readiness dimensions, including **29** subtopics assessed

The survey facilitated the detailed analysis of the EV sales readiness by country, by OEM, and by individual dealer. Examining sales readiness along the 29 subtopics guides the identification of opportunities for OEMs to improve.

3.1 Quantifying OEM EV sales readiness

We identified six key dimensions that characterize OEM readiness to sell EVs and to identify the critical assets in the sales process to boost their EV sales (Exhibit 17).

In-store experience. A superior in-store experience is essential for attracting undecided consumers to EV models and resolving their concerns. By designing a state-of-the-art in-store experience, OEMs and their dealer partners can showcase EVs in ways that both excite and reassure

Test-drives. Our insights about current EV owners and general consumers considering a purchase indicate that the experience of driving an EV can help seal the deal. By proactively marketing the EV driving experience and offering test-drives, dealers can help convince customers

Sales process. The way EVs are presented and explained to consumers is essential. A solid sales pitch should be crafted and delivered with the objective of convincing customers of the wide range of benefits of EVs and alleviating the pressing concerns that we identified in Chapter 2. Sales readiness is high if customers can be convinced that EVs are on equal footing with ICE vehicles on some dimensions and outperform ICE vehicles in other dimensions

TCO know-how. A detailed understanding of the true and holistic cost of EV ownership is an asset to OEMs. The ability to clearly communicate the TCO advantage of EVs is critical to winning consumers who care about the lifetime cost of car ownership

Battery know-how. The ability to provide clear answers to questions related to the EV battery, such as warranty and range, helps address a critical consumer concern. This includes, for example, the knowledge of what happens with the battery at the end of the warranty and then at the end of the battery's life – a question of concern for most consumers

Charging know-how. Though largely irrational, "range anxiety" is prevalent. OEMs should develop their capacity and capabilities to help consumers understand how charging works – including charger installation and usage – and provide individual, tailored advice to customers on how they can charge their vehicle, given their personal driving patterns.

Exhibit 17

We define 6 EV sales readiness dimensions to analyze to what extent dealers are addressing the prevalent consumer uncertainty preventing EV adoption

6 dimensions to quantify OEM EV sales readiness	Observed uncertainty among consumers (non-exhaustive)	
In-store EV experience Design a state-of-the-art experience to showcase EVs and consult customers	47% think new entrants, rather than incumbents, are leading the market	Innovative retail and flagship store experience drives consumer perception of EVs
EV experience during a test drive Advertising the driving experience by proactively marketing test drives	EVs are expensive and difficult to charge	EV driving experience with large potential to surprise and retain consumers (9 out of 10 would repurchase an EV)
EV sales process Present EVs on equal footing with ICEs	Black or white debate on EVs, e.g., expensive and eco-friendly	Wide range of EV benefits: high tech and performance, financially attractive, and eco-friendly
TCO know-how Explain TCO differences based on individual use case of customer	Batteries make EVs USD 5,000-10,000 more expensive than comparable ICE vehicles	14% lower TCO for A/B class EVs in the EU
Battery know-how Provide answers to customers critical concerns about range and warranty	Consumers concerned about battery lifetime and residual value	Many EVs come with a > 7 year warranty, and batteries may work longer than the vehicles lifetime
Charging know-how Exhibit charging solutions in-store and consult customers on installation and usage	>50% express charging/range as top concern	Some owners appreciate ease and convenience of charging

Source: McKinsey EV Consumer Survey 2019; McKinsey

3.2 There are striking differences in OEM EV sales readiness

The findings of our mystery shopping study highlight for OEMs and their dealers both the EV sales pitfalls and the opportunities on how to convince more consumers to buy EVs. In a cross-country comparison of OEM dealer outlets in Germany, China, and the US along the dimensions of EV sales readiness, Exhibit 18 illustrates these key insights. Exhibit 19 on page 30 further details the insights for selected subtopics.

The insights can be consolidated in the following 10 pragmatic recommendations of EV sales readiness.

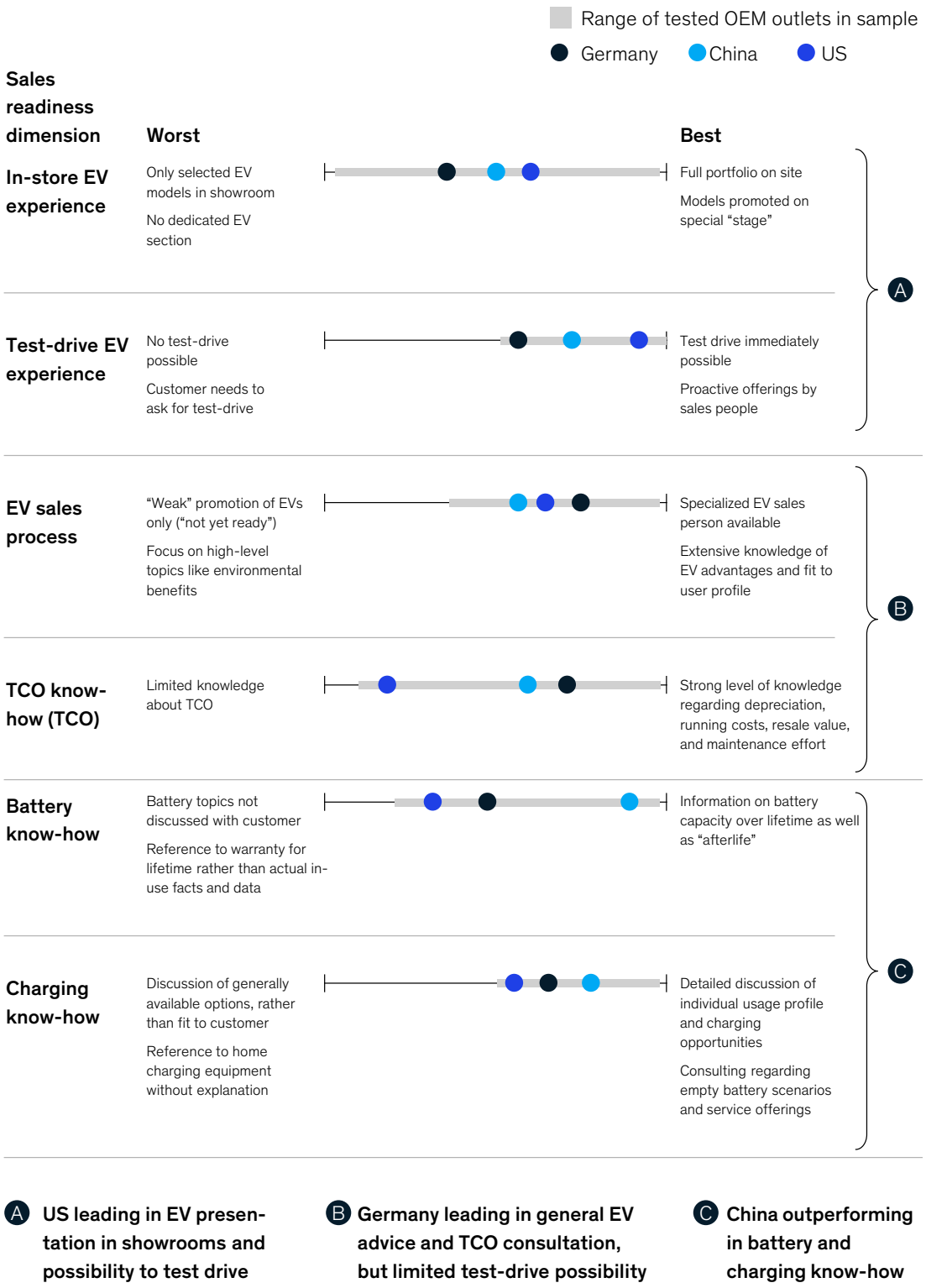
In-store EV experience

I **Present the complete EV product portfolio in all stores.** While almost all outlets in China (11 out of 12) had some EV models on display in the showroom, only two stores had the whole product portfolio on display at the outlet (either inside or outside the showroom). In the US, most outlets (12 out 15) had EV models available for inspection at the dealer site – e.g., parked outside the showroom – but the majority (10 out of 15) did not present the models in the showroom. As EVs move towards mainstream, customers will demand a variety of EV models to fit their different needs – this calls for OEMs to exhibit the complete portfolio of EVs.

II **Elevate EVs to a "special stage" next to ICE vehicles.** For an optimal EV in-store experience, the complete models should be presented side by side with ICE vehicles in the showroom and especially promoted as a new technology, as many consumers are not familiar with these vehicles. We have often observed the opposite. Except for outlets in China, EVs were typically positioned in a corner of the showroom floor or not at all. In one case, the only EV that the sales staff could show was the private car of a member of the sales staff.

Exhibit 18

A cross-country comparison of sales readiness shows large differences in TCO and battery know-how



Source: McKinsey EV Mystery Shopping 2019

Test-drive EV experience

III **Make test-drives available.** While almost all outlets in all three regions, particularly in the US, offered EV test drives, there were stark differences in how quickly customers could embark on a test-drive. In Germany, some customers were only able to test-drive an EV after having it delivered from the headquarters of the vehicle manufacturer, requiring a significant amount of time and the transport of the test vehicle over hundreds of kilometers. Making test-drives immediately possible on-site to consumers without any barrier (ideally at no cost and with the ability to make short-notice appointments online, via telephone or in-store) is the reference point.

IV **Proactively advertise test-drives.** We observed stark differences in the way that dealers advertised test-drives. While almost all tested dealers in the US (14 out of 15) proactively offered test-drives that were immediately available, this was only the case for a third of dealers in Germany (five out of 15). Dealers who do not proactively offer test-drives or require consumers to wait for test-drives (to request them a long time in advance) will be less successful convincing consumers of the EV driving experience.

EV sales process

V **Develop knowledge of all EV benefits among sales staff.** We observed that many dealer outlets across regions could list only a single EV benefit, such as government subsidies or environmental advantage. Individually, these are important benefits, however each is only a small part of a wide spectrum of benefits. As we indicated in Chapter 2, consumers are attracted by a diverse set of benefits. For a good sales pitch, there should be sales staff with extensive knowledge about the available EVs, who can advise consumers on how EVs fit their needs and pitch the benefits that fit each customer. While several outlets in the observed regions had sales staff on duty who were able to deliver EV sales pitches as specialized and as tailored as their ICE vehicle pitches, this was not the case across the board. For example, sales staff at only 25 out of 42 dealers globally (60 percent) mentioned the technical benefits (e.g., fast acceleration) of EVs to customers.

VI **Inspire and demand professionalism and enthusiasm among the entire sales staff.** The knowledge and professionalism of sales staff varied significantly. While several dealer outlets of OEMs seem to do a good job in the EV sales process, we did observe very weak and uninspiring promotions, such as, “EVs are not ready yet” or “EVs do not fit your needs”, without asking the consumer about his or her driving behavior. A balanced discussion of all powertrain options with the customer was only possible at 23 out of 42 outlets (55 percent). OEMs should monitor both their own and third-party dealer performance to ensure consistent delivery of an optimal EV sales pitch.

TCO know-how

VII **Be prepared to explain maintenance costs and depreciation to consumers.** Dealers in China and Germany advised customers about the TCO advantage of EVs but were still lacking important

Exhibit 19

Drill-down analysis of EV sales readiness (excerpt): detailed analysis of subtopics covered by the mystery shopping indicates topics that need improvement

Score per country, average of all stores of all brands tested[1]

0-4.9 | 5.0-7.9 | 8.0-10.0

EV sales readiness Dimension	Subtopics (selection)	China	Germany	US	Selected observations and explanation
In-store EV experience	EVs visible/presented in showroom	9.2	7.3	3.3	Dealers in US have EVs often only parked on-site but not in showroom
	Entire EV portfolio on site	1.7	0.7	8.0	
Test drive EV experience	EV test-drive proactively offered and immediately possible	7.5	3.3	9.3	Test drives in Germany often only possible by appointment
EV sales process	Highlighting of real benefits of EVs (instead of simply justifying common prejudices)	9.2	8.7	4.0	Dealers in US lag in pointing out benefits
	Mentioning of environmental benefits (e.g., less pollution, CO_2 reduction, noise)	0.0	8.0	4.7	Environmental benefit less important factor
	Pointing out of special EV subsidies/offers	8.3	7.3	9.3	Subsidies are consistently used in sales pitch
TCO know-how	Knowledgeable about TCO (compared to an ICE)	10.0	9.3	1.3	Dealers in US don't know about depreciation and electricity costs
	Knowledgeable about vehicle depreciation after 1 year	0.0	4.7	2.0	Depreciation unknown to most dealers
	Explanation of charging costs	10.0	8.0	2.0	Dealers in US unable to explain TCO advantage
	Knowledgeable about maintenance schedule/effort (cost) compared to ICE	7.5	6.7	4.7	Many dealers in US stated that maintenance is identical (incorrect)
Battery know-how	Knowledgeable about lifetime of battery	9.2	5.3	4.7	Lack of know-how about battery lifetime and warranty outside China
	Knowledgeable about what happens after useful life of the battery	8.3	4.7	2.0	
Charging know-how	Information on public charging possibilities	10.0	7.3	8.0	Tips for chargers in local areas and references to charging apps given
	Information on real driving range under normal conditions	9.2	10.0	8.7	Dealers often explain both nominal and typical driving range
	Explanation of options in case of empty battery	3.3	4.7	5.3	Dealers consistently lack answers on what to do if battery is empty

1 Scale from 0 = worst performance to 10 = best performance
Source: McKinsey EV Mystery Shopping 2019

knowledge about maintenance efforts, expected depreciation, and resale value[7]. Dealers need to improve their fact base to convincingly answer TCO- and maintenance-related questions and questions about the maintenance effort. The vague statements we observed like "EVs could be less expensive in maintenance costs" are neither sufficient nor convincing. Several dealers in our study were unable to offer any piece of advice in this area and thus further unsettled the consumer. In some instances, our test buyers were provided with incorrect information such as "the maintenance costs are the same [as for ICE vehicles]".

Battery know-how

VIII **Build Know-how among sales staff on battery lifetime and quality.** Only dealers in China demonstrated solid knowledge about the topics of lifetime, capacity, and the "after-life" of batteries. Mystery shoppers in the US and Germany typically received only standard responses, such as, "the battery warranty is seven years." To best alleviate consumer concerns, dealers need to answer consumer questions regarding the battery (including the different warranty options and diminishing capacity over the lifetime of the battery) thoroughly and individually.

Charging know-how

IX **Educate consumers interactively on how to navigate charging in every-day usage.** Beyond the basics of charging – such as public charging facilities, the different charging products for home, and the driving range under normal conditions – it is the tailored advice offered by sales staff that distinguished some dealer outlets from others. To excel, knowledgeable sales staff should guide the consumer through their new every day life with an EV, e.g., explaining how charging poles at home, at work, or during a shop visit can be utilized, given the specific situation of the individual customer.

X **Respond to consumer range anxiety with tailored advice and solutions.** Across regions, we observed most dealers falling back to standard responses to answer customer concerns about battery range and charging options. Sales staff at less than half of all outlets globally (19 out of 42) could answer questions about, e.g., what customers should do if the battery unexpectedly becomes flat. Clear guidance on what to do in such a situation paired with a superior service offering (e.g., provision of emergency power, etc.) is necessary to convince the customer. Moreover, dealers should provide consumers with a convenient option to obtain a replacement car for ultra-long drives when going on vacation (e.g., one free voucher per year).

Our observations suggest that decisive action is necessary. Both OEMs and dealers have several opportunities to improve the sales experience for consumers. A superior sales experience is critical to captivate consumers and facilitate their EV purchases.

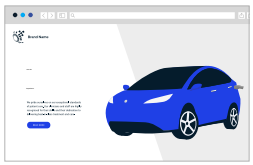
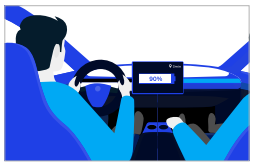
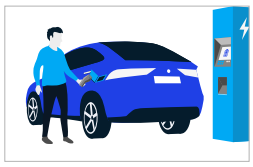
7 Given the technological uncertainties of batteries, it is, of course, difficult today to forecast the residual value of EVs. Dealers could approach these uncertainties in scenarios (e.g., assuming a specific value of the battery after 100,000 miles driven).

4. OEMs can boost EV adoption by improving the consumer experience

Based on expert and customer interviews, surveys, and proprietary analyses, we have identified five critical make-or-break touch points for gaining a new EV customer or holding on to an existing one (Exhibit 20): the digital moment of truth, the in-store moment of truth, the driving moment of truth, the charging moment of truth, and the service moment of truth. In this chapter, we discuss the actions to be taken by OEMs at each moment of truth in order to win customers.

Exhibit 20

To boost EV adoption, OEMs should focus on mastering five moments of truth

Digital moment of truth		Create a superior online experience with tailored customer advice and omnichannel integration
In-store moment of truth		Design a modern store experience to optimally showcase EVs and provide comprehensive know-how
Driving moment of truth		Lock in consumers on the EV driving experience via test drives and shared-mobility solutions
Charging moment of truth		Offer a seamless private and public charging experience to address consumer concerns
Service moment of truth		Provide state-of-the-art service with remote maintenance and world wide service excellence

Source: McKinsey

4.1 Create a superior online experience

Provide a superior Website experience, as most consumers (80 percent and rising) research online when considering a car purchase. The average car consumer spends 14 hours online and one hour offline before buying a vehicle[8] . Ease of experience is key in this moment, and it requires a personalized, modern online store setup. For example, premium OEM Websites often center on a car configurator as the main feature, with sophisticated configuration options yielding millions of possible choices[9] , yet little explanation of the future car experience is given to the customer. In contrast, rising EV-native companies often feature simple and intuitive car configurators with much fewer but easier-to-understand choices. For example, they might offer only three versions labelled "basic," "standard," "performance" for the whole engine and power train configuration and enable further customization possible after the car purchase, making choosing a car as easy as selecting a smartphone[10] . For each option, OEMs could interactively explain the envisioned use cases and how the car can be used in everyday life (e.g., detailing for each option how often the car needs to be charged per week for a typical consumer). By keeping the EV experience at the center and interactively showing how consumers can drive and charge their EVs, OEMs should use their online presence as an opportunity to focus on the potential benefits and mitigate potential concerns.

Establish an online store for EVs, as 50 percent of car consumers are comfortable with signing contract a online[11] . Our research suggests that a superior online experience may be even more important to potential EV buyers. EV consumers are on average more tech-savvy with, e.g., 12 percent of BEV customers in the US having made the actual purchase transaction online. Just as important is the seamless integration of online channels with offline sales channels. Integration provides value to the customer as well as opportunities for OEMs to recover margins lost to dealers. Setting up showrooms in city centers or shopping malls complements online shops and provides customers with a low-hurdle opportunity to see the vehicle before purchasing it online. By linking online sales with offline marketing opportunities, OEMs can offer consumers a modern, convenient shopping experience that is cost efficient at the same time.

Develop competitive leasing models and offer EVs in mobility subscription services to adapt to changing consumer preferences. Since a higher share of current EV owners lease their vehicle than ICE vehicle owners (e.g., approximately 80 percent of BEVs in the US are leased), providing competitive leasing models to customers is imperative. Offering convenient leasing models with a mobility guarantee eases any residual uncertainty about the resale value and battery warranty among customers. At the same time, as mobility subscription services (i.e., car-sharing apps and ride-hailing apps) are becoming ubiquitous, OEMs should also partner with mobility service providers to feature EV models. Offering EVs in shared mobility services not only accesses a growing market but also provides the opportunity to convince consumers of the EV driving experience.

8 Data for average car purchase (ICE vehicles and EVs); source: McKinsey Center for Future Mobility
9 Multiplying all possible options for a top model of a large premium OEM yields more than one billion of possible combinations
10 Smart phone manufacturers have limited the choices to few basic choices, e.g., a choice between three colors and three different memory options but offer ample possibilities for (digital) customization via app stores
Source: McKinsey Auto Retail Survey

Offer digital advice and service apps to counter prevalent myths and enhance the customer experience. Offering additional electronic services, such as specific apps that help customers to calibrate their driving behavior before buying an EV or manage their car (e.g., smart-charging apps to determine when to charge the EV) has become quite common. Several EV manufacturers even offer an "app store" and integrate the car seamlessly with customer mobile devices. Customizing the experience is an effective, cost-efficient approach to achieve the individualization and connectivity that customers demand. At the same time, it paves the way for a more continuous monetarization that will become more common in the future mobility landscape. Given the trends towards smarter, more autonomous cars, customers will increasingly be willing to pay for features enabled by additional software that can be acquired after the initial car purchase. Future EV customers will want their digital life to extend from customer mobile devices to their car.

4.2 Design a modern store experience

Change from car sellers to trusted advisors who interactively address consumer concerns and provide advice using innovative methods. Customer concerns need to be fully and proactively addressed to turn EV consideration into EV purchases. Many dealers only provide standard answers rather than tailored, trusted advice. To excel in this regard, technological aids, such as personalized, tablet-based visualization of costs tailored to individual driving behavior or the in-store demonstration of wall chargers can be implemented. Answering questions before they are asked and anticipating and allaying fears before they arise is key. Given the increasing importance of online shopping, the role of sales staff at dealer outlets is augmented too. Rather than a focus on transactions with the aim of selling as many EVs as possible, dealer staff should assume the role of knowledgeable, trusted advisor to their customers. The in-store experience has the potential to win over customers or lose them forever.

Fully and prominently display the whole EV portfolio, as 70 percent of customers see the physical car experience as the main reason for their dealer visit[12] . As consumers increasingly obtain information from the internet, the relevance of the physical car experience is elevated. Dealers should leverage this by centering the customer in-store experience on product representation ("showroom") rather than the typical set up of large desks between just a few cars.

Address younger, urban, tech-savvy customers – the early adopters – through customized marketing and "experience stores" within cities/shopping centers. Because our findings show that current EV owners – the early adopters – mostly live in cities, OEMs should establish urban consumers first by providing a superior in-store experience in city center outlets and installing flagship stores in city centers. This customer segment will be easiest to convince, as they typically drive short distances (i.e., range anxiety less prevalent) and are more affected by EV-friendly regulations in cities that are being unveiled around the globe. Once this customer segment is convinced, they will help to spread the word about the benefits of EVs.

4.3 Lock in consumers on the EV driving experience

Move the test-drive experience from "hard to get" to "instantly available" with online booking tools. Given the importance of regions on the EV driving experience and the observed hassles in arranging test drives in some regions, OEMs should focus on making the booking of test-drives in person and via Websites as easy as possible. Consumers should be able to book test-drives free of charge on short notice via the internet, telephone, or in-store.

12 Source: McKinsey Auto Retail Survey

Advertise EV test-drives to all customers, rather than having customers ask for them. Test-drives should be offered proactively at dealer outlets and with minimal hurdles. Proactive marketing to promote EV technologies through special events, for example, can boost customer conviction among the average consumer, who – unlike young, tech-savvy individuals who are less wary of and more willing to adopt new technology – need guided introductions to new technologies.

Create other low-barrier, hands-on "EV experience" opportunities beyond test drives. Partnering with taxi companies, and shared mobility providers, such as car-sharing apps or ride-hailing platforms is another important method to pull customers into the EV experience. On average, 32 percent of consumers would pay extra for an EV when booking, and there is potential here to reach and influence consumers. Customers who become familiar with EVs in this way get a sense of the EV driving experience, including – in the case of car sharing – developing an understanding of how charging works.

4.4 Offer a seamless charging experience

Provide a seamless charging experience in the public, semi-public, and private space. Offering seamless private and public charging experiences to consumers addresses their two most critical concerns regarding EVs – battery/charging and driving range. A seamless charging experience requires that customers can easily find charging stations, use them without technical difficulties, and bill the costs transparently to a single customer account. Currently, as more charging providers enter the market, a main drawback is the lack of inter–operability of existing services. For example, there are dozens of different smartphone apps from charging infrastructure providers available to pay for the charging that typically require a separate registration – making the customer experience cumbersome. Moreover, a critical customer concern in some regions is the charging costs – the primary concern regarding charging in Germany (Exhibit 21). Good cost transparency and reasonable prices at public charging poles – especially in the long run – are necessary to convince many consumers in these markets. Overall, consumers will only accept EVs in the long run if they can charge them easily, at a reasonable cost, and at any public charging pole close to them.

Increase density of (semi-)public charging networks. While currently many early adopters of EVs charge at home, future growth is only possible if consumers without the option of installing a charger at home can also easily charge their vehicle – e.g., while parked on the street. Making charging stations available when and where EV drivers need them by making them accessible, available, and easy to find is key as currently 43 percent of all charging instances of current BEV owners occur at public charging stations. To build dense charging networks, OEMs need to engage in partnerships with governments and infrastructure providers to install public charging stations and at the same time enable retailers, office locations, and managers of residential buildings to install charging stations as well.

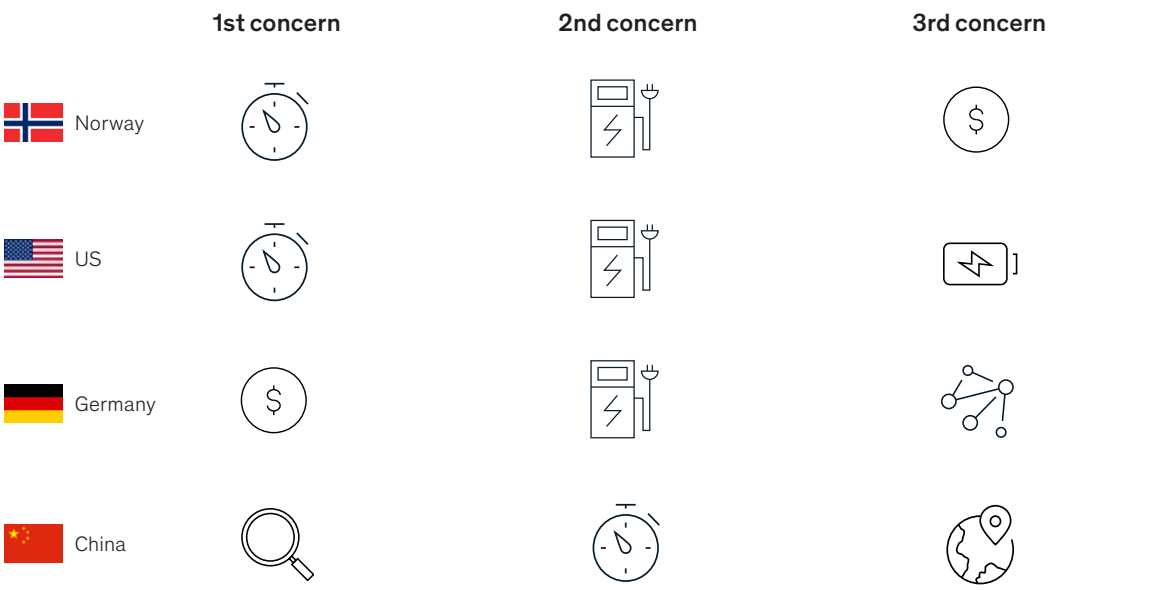
Increase the availability of fast chargers to counter the most critical consumer pain point. To manage consumer demands for fast charging – the primary concern in two out of the four markets we analyzed (i.e., in Norway and the US, Exhibit 21) – the provision of fast chargers seems critical. To enable consumers to take long, cross-country trips (e.g., driving for a vacation) with EVs, an expansion of the fast-charging network is key especially along highway routes. At the same time, by advertising a new "charging lifestyle" in which cars are charged for 30 minutes during a lunch break or a visit to a point of interest, a major pain point can be turned into an opportunity.

Provide smart charging, as 64 percent of BEV owners would like to or already participate in smart-charging services. Facilitating smart charging is desirable not only because customers demand it (to profit from lower electricity prices in off-peak times, among other reasons), but also because it provides a meaningful way to manage the charging habits of the growing number of EV owners to balance the stability of the electric grid.

Exhibit 21

EV owners are mostly unsatisfied with the speed of charging and availability of public chargers

Key concern points regarding EV charging per country



Source: McKinsey EV Consumer Survey 2019

4.5 Provide a state-of-the-art service experience

Car companies need to be customer centric, but about 70 percent of car customers do not perceive OEM as customer centric[13]. A step change in the after-sales service is required. In the context of EVs, OEMs can introduce a new level of customer-centric service offerings. OEMs may consider, for example, building a close-knit network of certified service providers in addition to their own outlets to quickly execute guaranteed services, such as battery changes or other critical battery services. In addition, they may provide recharging services in case of an empty battery or provide replacement vehicles for particularly long journeys (e.g., during a move or when going on vacation). With this model of service, customers are more likely to believe that car companies are looking out for them even after they have made the purchase and feel more comfortable switching to an EV as their primary vehicle.

Differentiate by offering continuous connectivity and digital maintenance planning, as 40 percent of consumers would switch car brands for better connectivity. Online management of cars has become a standard for several car brands and will continue to be an important sales criterion for many consumers. We have already established that EV consumers are tech-savvy, but this applies to more than vehicle research and purchase. They also demand state-of-the-art after-sales services that are always available and connect to their smartphones. This includes, in particular, the online management of all after-sale services and software updates via the internet. For example, an online account accessible via a smartphone app and online website could host all service-related information regarding the EV, including alerting the customer when a replacement of parts, such as the brakes, is necessary and offering the possibility to update the software online as new software versions or features become available.

OEMs and their dealer partners can take targeted measures to ensure that they master these five moments of truth – helping to build the case for EVs in the eyes of the customer. However, the relevance of each factor depends on the region and the car brand itself, thus requiring a balanced discussion for each OEM regarding what they should focus on.

13 Source: McKinsey Center for Future Mobility, *"The Future of Automotive Retail"*

Outlook

Sparked by increasing environmental awareness across the globe and consumer demand for cleaner cities, governments around the world are going to push even further for EV adoption. Many national governments and local municipalities alike have implemented a variety of "sticks" (restrictions and fees tied to ICE vehicles) and "carrots" (purchase subsidies and greater street access tied to EV vehicles) to foster greater EV adoption.

With all incentives implemented, EVs would be on a fast track towards widespread adoption. In fact, OEMs are planning to release an unprecedented number of EVs to market in the coming years – 400 new BEV models by 2025. The challenge now is to bring consumers more fully onboard. A small segment of tech-savvy consumers is already leading the adoption wave, but a more critical mass of consumers will have to become more comfortable with the idea that EVs can reliably and comfortably get them from Point A to Point B.

Getting started on improving OEM EV sales readiness

The conditions for a large-scale consumer pull for EVs have never been as positive as they are today. For widespread adoption to become a reality, though, consumers will need to be convinced, in greater numbers, of the upsides of EV ownership. It has become apparent from our research that consumers will only switch to EVs if they meet their needs. The good news for OEMs is that (i) objectively seen, the benefits of EVs clearly outweigh the concerns, and (ii) that OEMs are in the driver's seat when it comes to pulling the additional levers necessary to convince consumers that EVs can work for them. In other words, OEMs in particular can make a decisive contribution to consumers understanding EV benefits – and that those benefits outweigh their concerns.

At the same time, OEMs should act quickly to shape the ecosystem and differentiate themselves early by understanding customer needs. OEMs who lead in customer centricity will be able to attract new customers. Furthermore, it could well be that those OEMs who provide a superior EV experience will be able to reestablish customers who have chosen and cultivate new long-term relationships, especially in the premium segments.

Assisted by the analytical toolkit we have developed (i.e., the EV consumer survey and the six EV sales readiness dimensions), OEMs have several opportunities – online, in the showroom, on the road, and in the repair shop –to educate and excite consumers about EVs and build their confidence in the idea that EVs are the reliable and affordable next wave of individual mobility. OEMs will want to assess their strengths, consider their options, and follow a smart approach to ensuring that the EVs they are bringing to market are purchased by a growing number of customers.

The advent of EVs marks the second turning point of the automotive industry

At the beginning of the 20th century, horse-drawn carriages were replaced by cars as the ubiquitous means of transportation in cities within just a few years – marking the first turning point of the automotive industry.

The advent of EVs marks the second turning point of the automotive industry and will be a critical milestone towards the future of the industry. This time, the disruption of conventional ICE vehicles by EVs will be strongest in cities.

OEMs should, therefore, focus on big cities with electric mobility. The OEMs that master the five moments of truth of electric mobility will also be the first ones to develop a profitable EV business model and gain a competitive edge.

While these technological developments bring numerous opportunities by themselves for OEMs, suppliers, and after-sales players to succeed in new markets, business models will also have to transform. Future key technological developments in the industry will be related to connected and autonomous car technologies; a shared vehicle ecosystem; and more connectivity among the vehicle, the driver, and his/her devices. OEMs that excel in EV technology will likely be in a better position to also shift gears and make the transition into these future business models.

The change from "vehicle as a product" to "mobility as a service" will bring new experiences to consumers and provide ample opportunities for automotive players across the value chain to transform their business models into subscription models and lifecycle monetization. In the decade ahead, OEMs will need to master both technological development and the transition to new business models to succeed.

A future beyond brick and mortar – disruptive change ahead in automotive retail

How to leverage the current crisis to leapfrog into the next normal.

September 2020

bz Jan-Christoph Köstring, Thomas Furcher, Philipp Maximilian Lühr, and Niels Dau

Introduction and key messages

Disruption ahead – shifting customer expectations, new mobility offerings, and technological disruptions such as digitization, vehicle connectivity, and electrification are driving the transformation of automotive retail at an unprecedented speed and magnitude, radically changing the status quo. The current COVID-19 situation is further accelerating the ongoing transformation and leap frogging the adoption of digitally-enabled car buying and online sales models. Moreover, the current crisis raises the cost consciousness of OEMs and dealers and facilitates critical decisions on further outlet consolidation, leaner retail formats, direct customer access, and alternative sales models.

Consumer confidence has considerably dropped as a result of the Covid-19 crisis and is also impacting car buying intents. A McKinsey car buyer survey from September 2nd to 4th, 2020, indicates that new car purchase intent in the US is still ~20% below pre Covid-19 levels, while Europe and Asia have already recovered from their lows in April and May (minus ~10 to 40% depending on country) and currently show a drop in purchase intent of ~10% respectively ~5% compared to pre Covid-19 levels. From the remaining respondents with purchase intent around half indicate that they will delay their purchase for at least another 4 months. Economic reasons (e.g., reduced income) dominate the decision to delay the car purchase mentioned by around ~55 to 60% of respondents across countries and become even more relevant, whereas delays due to health concerns (e.g., no safe test drives offered) indicated by ~25 to 35% of respondents keep decreasing. Additionally, around ~10 to 15% of respondents are also holding back to wait for subsidies and discounts to support their purchase. Our survey also shows that this drop is significantly impacted by the primary channel usage. Consumers in the US that are buying their car mainly online are less likely to change their purchase intent (drop by 2pp) than consumers that planned to conduct their buying journey "offline" and purchase in person at a dealer (drop by >8pp). This trend caused a significant rise in the adoption of remote sales tools and online sales channels since the Covid-19 outbreak for both OEMs and dealers on a global scale and will likely continue in the upcoming months. Covid-19 and the current economic situation alarmingly disclose the necessity for players in the automotive industry to act now and to rethink their retail strategies.

Beyond COVID-19, an overhaul of the current automotive sales model has long been discussed due to underlying constraints that affect customers, dealers, and OEMs alike. From a customer perspective, the current retail model cannot fully accommodate the diverse set of realities in terms of customer expectations, needs, and behaviors. Across all regions and customer groups, only 1 percent of the customers we surveyed were "fully satisfied" with their overall car-buying experience. From a dealer perspective, innovative mobility concepts, digitized retail formats, and new market entrants drive significant deterioration of dealer margins, congruent with 88 percent of automotive executives expecting that at least some dealer groups will not survive the upcoming disruptions. From an OEM perspective, the current automotive retail model equates to spending up to 30 percent of potential gross revenue on vehicle distribution in the form of wholesale, structural, and tactical costs of retail. Moreover, 75 percent of automotive executives believe that retail is one of the main battlegrounds where new players will attack to gain customer access, occupy critical elements of the car-buying journey, and gain a significant share of revenue and profits.

Given this context, the future of automotive retail has understandably become a top agenda item in many boardrooms. A noticeable example for this is Volkswagen's announcement in 2018 to "restructure its sales model" by issuing new dealer contracts in Europe becoming effective in April 2020. Other major automotive players such as Daimler and Toyota have announced similar moves over the past few months with notably accelerating speed and clarity (Textbox 1).

Textbox 1:
Announcements of new automotive retail models (selection)

Volkswagen: Digitized and more direct sales model in Europe

Volkswagen's new sales model aims to "provide seamless individual round-the-clock support for customers," expanding online sales, enabling direct sales models, and targeting customers more individually through new sales

and service formats such as city showrooms or pop-up stores. In addition, Volkswagen's agreement with the Volkswagen and Audi Partner Association on an agency model for the ID. family marks an important milestone and allows Volkswagen to be the customer's direct contractual partner for the first time.

Daimler: "Best Customer Experience 4.0" and direct sales

Daimler aspires to "offer its customers seamless luxury experiences and lasting memories – regardless of the time, place, or channel they are using. Buying a Mercedes-Benz should become as easy as ordering a book." The "Mercedes me"- ID allows customers to choose flexibly between different sales channels using a single profile. To support its goal, Daimler shifted to a more direct sales model, initiating pilots in Sweden and South Africa in 2019 to sell new cars directly to customers at a uniform price – regardless of whether the customer buys the vehicle via an online or traditional sales channel. In recent months, this model has also been adopted in Austria and partly implemented in Australia for the EQC and other EQ electric models to be launched by the end of 2023.

Toyota: Drive Happy Project in New Zealand

Toyota's Drive Happy Project, launched in New Zealand in April 2018, aims to eliminate several customer pain points at once along the car-buying journey, from online configuration, to extended test-drives, to seven-day money-back options. At its core, Toyota implemented three radical changes. First, the shift to a direct sales model where new vehicle stock is centralized country-wide in three pools and owned by Toyota, which alleviates sales pressure from stock on dealerships. In this model, dealers are compensated via a handling fee for providing specific retail services such as test-drives and vehicle processing. Second, sales reps targets in dealerships are focused on customer satisfaction, not volume, to incentivize customer-centric behavior. Third, prices are haggle-free "Toyota Driveaway Prices" to enhance transparency and facilitate omnichannel purchases.

Sources: company announcements and media coverage

However, staying ahead of the current disruptions in automotive retail will require more from OEMs and their retail partners than simply moving their operations online or going direct. Changing consumer preferences and the non linear speed of change make it difficult for OEMs and dealers to transform their retail models, and it is safe to say that no single OEM or dealer has fully "cracked the code" yet. Inaction, on the contrary, is not an option. The strategic direction of an automotive retail model will likely determine the future success of an entire company, and any step in the wrong direction will be difficult or even impossible to take back. A commitment to innovation in automotive retail is the imperative – and the time to get started is now.

Against this backdrop and based on our extensive research and analyses (Textbox 2), we will provide a comprehensive perspective on three key questions that are currently a top priority for automotive OEMs and dealers:

1. Why exactly is the traditional automotive retail model so severely under pressure at present, and what do OEMs and dealers need to know about changing customer preferences and technological megatrends currently impacting the automotive retail space?
2. What are the compelling future retail model options for OEMs and dealers to stay ahead, and which capabilities and changes do they require?
3. How can individual OEMs and dealers effectively start their transformation journey towards a robust and future-proof retail model?

Textbox 2:
How we derived insights for this report:

1. Launched a comprehensive consumer survey in China, Germany, and the US among more than 3,000 car buyers
2. Conducted dozens of interviews with executives from the automotive industry (both OEMs and dealers), mobility players, and start-ups
3. Worked with an agency to gain firsthand insights into today's retail experience and sales readiness for electric vehicles (EVs)
4. Accompanied a dozen car buyers in the US over a two-month period to gain deeper insights into the emotional experience and consumer behaviors of car buying.

In our attempt to answer the above questions, we distilled three key messages regarding the future of automotive retail and how OEMs and dealers can stay ahead of the disruptive changes in progress:

— The traditional automotive retail model is under severe pressure because:

  • Customer preferences are evolving and significant pain points at various stages along their car-buying journeys persist

  • The ACES trends (autonomous driving, connectivity, electrification, and shared mobility) plus digitization will have a major impact on the current automotive retail landscape.

— OEMs and their retail partners are "stuck in the middle" due the to varying needs of today's and tomorrow's car buyers and how different players in the market are responding to the changing retail landscape. As our research indicates, their strategies for the future need to become much more diverse and will diverge from the current retail model to an extent not seen before. Because of this, a strong need is emerging to carefully plan and assess their transition into the future of automotive retail. To this end, OEMs and their retail partners should consider our comprehensive perspective on the strategic options currently available to them. From the total number of options, we have defined five different archetypes of future retail strategies: 1) OEM building on dealer as entrepreneur, 2) dealer as execution agent, OEM in control of new-car sales, 3) OEM fostering competition, dealer as exchangeable execution provider, 4) OEM owning the retail approach, and 5) OEM handing over to importer.

  While each of these retail strategies appears fundamentally different from the others and difficult to implement at first sight, we strongly believe that a combination of approaches may be best for any given OEM or dealer. Specifically, a region-by-region and brand-by-brand approach to a future retail strategy means that a single OEM or dealer may adopt two or more of the archetypes defined above. Our research highlights parts of the different natures of automotive markets in terms of maturity regarding ACES trends, legislation for direct sales, and affinity for online sales – as these determine not only the speed, but also the direction of change. In addition, OEMs' market positions differ strongly by region, as do the ecosystems they face.

— At the same time, it is important to quickly begin preparing for the transformation of automotive retail, given the magnitude of change and the implied amount of time that these changes will take within larger organizations. Getting started sooner rather than later becomes even more important when considering the amount of time, it will take to implement changes across the retail networks, which are built on long-term partnerships and investments. To this end, OEMs and dealers should start with five "no-regrets" moves, which will also enable them to prepare themselves to take on and master ambitious future challenges, such as big data and advanced analytics in automotive retail, in the medium and long term. These moves are:

  • Define strategic focus areas and create alignment within the organization

  • Investigate direct and online sales models

  • Consider transaction-price steering as a true game changer

  • Define measures and leaner formats to reduce retail costs

  • Build the necessary capabilities and adapt the organization.

Each of these topics will be explained in more detail in the following chapters.

1 The traditional automotive retail model is under severe pressure

Automotive retail as we know it is facing a radical change that is largely driven by shifting customer expectations and technology trends. Customer expectations for buying a car vary strongly; however, common points of joy (e.g., test drives) and common pain points (e.g., online experience or price negotiation) can be found along the journey. On the technology side, digitization and key ACES trends will fundamentally influence the retail landscape and are described in more detail in Chapter 2.

The myriad ongoing efforts and approaches to transform automotive retail reveal the intense uncertainty associated with both what today's and tomorrow's car buyers actually want and how different players are responding to the changing automotive retail landscape. In light of COVID-19, OEMs and their retail partners are at a cross-roads and should use the rising momentum to accelerate their transition into the future of automotive retail, which goes far beyond simply moving their operations online.

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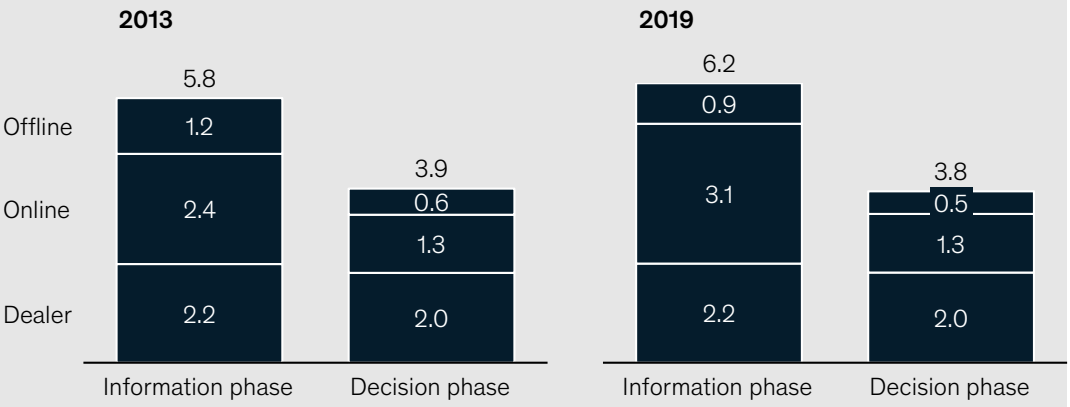
Analysis of data on the car-buying journey from various information sources – consumer surveys, industry expert interviews, car-buyer "ride-alongs" – reveals a comprehensive picture of a diverse set of realities in terms of customer expectations, needs, and behaviors, and shows some interesting developments over time (Textbox 3). Becoming experts in customer-centric and multichannel journeys will be crucial for OEMs and dealers to be able to serve a wide range of individual customer preferences while seamlessly sharing information between channels and retail partners. This diversity becomes clear when asking car buyers about their ideal car-buying experience, with about one fifth hoping for a fast, efficient, no-frills experience, while more than one in ten expect a personalized, and hightouch interaction.

Textbox 3:
Change of car-buying preferences over time

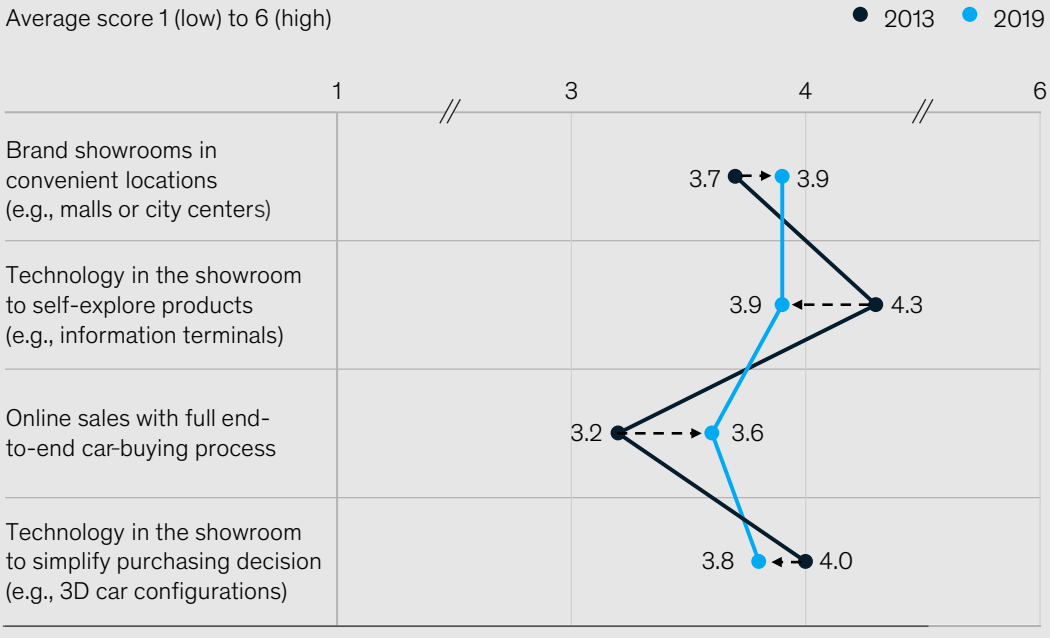
Connecting our recent and historic research reveals a change in car-buying preferences over time. While the number of sources used along the car-buying journey stayed relatively stable, the mix has further shifted towards online sources with an increasing influence of third-party websites. This trend is also reflected in the rising importance of innovative retail formats such as brand stores in convenient city locations as well as online sales. In return, the need for physical in-store equipment such as expensive virtual reality or digital technologies has dropped, driven by a high share of car buyers who use digital and mobile offerings instead and focus their dealer visit primarily on the physical experience of the car.

Number of sources used along the car-buying journey



Source: McKinsey

Importance of innovative retail formats and elements



Source: McKinsey Automotive Retail Consumer Survey (US, China, and Germany)

1.1 The current retail model does not satisfy customer expectations anymore – pain points across the car-buying journey persist

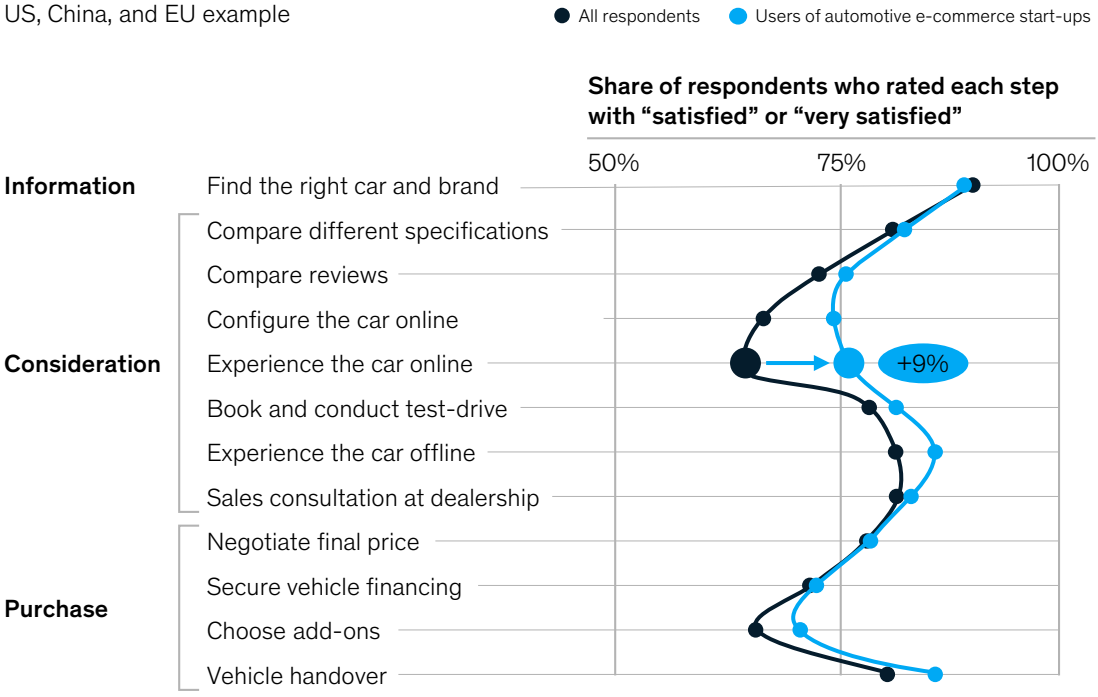
We find a stable pattern of persistent pain points across all geographies and customer groups in three particular stages of the journey: the online experience and configuration of a car, securing vehicle financing, and the selection of add-ons. Our research also shows that customers who heavily use the research, experience, and shopping platforms of automotive e-commerce start-ups in their car-buying process are, on average, more satisfied than others with their car-buying experience, particularly with the digital experiences (Exhibit 1).

To better understand the car-buying process, we followed over a dozen people from the US every week for two months throughout their car-buying journeys. These "ride-alongs" gave us additional insights from a customer point of view. It turned out that moments of real excitement as well as pain points are highly individual but can be grouped along four distinct groups of car buyers (Textbox 4), which we will further characterize in the subsequent chapters. The wide range of car-buyer preferences and behaviors underlines the need for a customer-centric and omnichannel setup that provides a deep understanding of the customer along the entire car-buying journey and beyond.

Exhibit 1:

Automotive retail disruption

US, China, and EU example



Average duration of a customer journey: ~6-8 weeks

Source: McKinsey Automotive Retail Consumer Survey (US, China, and Germany)

Textbox 4:

We accompanied a dozen car buyers in the US over a two-month period to gain deeper insights into the emotional experience and consumer behaviors of buying a vehicle.

Will always need to see the car up front

Roxanne
50 years old
Lives in metropolitan area

"I am a preparation perfectionist and love to do online research; however, I will always need that feeling of driving the car and touching, feeling the materials."

Wants to lease via online contract

Niloo
30 years old
Lives in urban area

"The financing decision part is the most challenging for me – I don't really know how to handle the different options; online could be a solution."

Would consider buying a car online

Stephen
25 years old
Lives in suburban area

"I do feel nervous about the journey as it is a major purchase and I'm on and off about the vehicle type, brand, and model; however, I'm also excited to get a new car."

Is excited to see and test new cars

Rita
46 years old
Lives in suburban area

"Researching new cars is really enjoyable – I always find new insights/equipment options that I haven't come across before."

Key findings from the ride-alongs include:

- Each buying journey is distinct and moments of real excitement are highly individual: Roxanne's most exciting moment was test-driving her preferred car, while Stephen was most excited once he had finished his online search with a forced ranking list of preferred car models.
- The behavior of car buyers strikingly illustrates the need for a customer-centric omnichannel setup – and the capability of the seller to manage it: Rita, for example, went all over the place in her journey and used Facebook, car newspapers, OEM and dealer websites, as well as several dealer visits.
- Satisfaction levels for individual steps of the buying journey can be highly subjective and need to be managed individually: Niloo felt well informed about the options to lease her car, including all the required details, but the formal paper work and wordy contracts made her anxious at a moment that is very critical for closing the sale.

1.2 Customers' online expectations are rising and acting as a catalyst for change across the industry

Like other industries, the online portion of today's car-buying journeys is becoming larger and more important, driven by the general increase in consumers' affinity for online channels and the clear advantages to OEMs and dealers of using the internet as an additional information and sales channel. Thus, moving online seems to be a natural step for many OEMs and dealers, considering that over 80 percent of customers already use online sources during the car-buying process.

Our research indicates that offline touch points are still a very important part of the journey, especially for the final purchasing decision, but online ones are increasingly shaping customer perception and play a major role in the information and consideration phase (Exhibit 2). Beyond using the internet for research and comparison, about half of the customers we surveyed would consider purchasing their next car online. The key reasons for purchasing online are time savings, the hope for better prices through online price transparency, and the conveniences of online shopping (e.g., no store visits required). Nevertheless, there are cases, such as in China and the US, where legal limitations constrain opportunities to fully purchase a car online from the manufacturer.

This leads us to believe that online sales will make up 10 to 25 percent of global automotive sales by 2025. Several companies have announced their internal targets, such as Peugeot with 100,000 online sales by 2021 or Mercedes that aspires to sell 25 percent of its new cars online by 2025, while many others, including Hyundai, Volvo, Jaguar Land Rover, Mitsubishi, and BMW, are operating online sales pilots.

>80% of customers already use online sources during the car-buying process.

Exhibit 2:

Offline is still important, but online is becoming key

Offline touch points still represent key parts of the journey …

2–3 dealership visits per customer is still the norm as part of the average car-buying journey

~70% of respondents see the dealership visit as a prime opportunity to physically experience the car

Dealership visits are the **No. 1** factor influencing purchasing decisions – followed by test-drives

… but online touch points are increasingly shaping customer decisions and experiences

During the customer journey, online sources were used **>20%** more often than offline sources

>80% of respondents use online sources during the consideration phase

>60% of respondents would perceive booking, paying, and reviewing additional services online as (very) appealing

Source: McKinsey Automotive Retail Consumer Survey (US, China, and Germany)

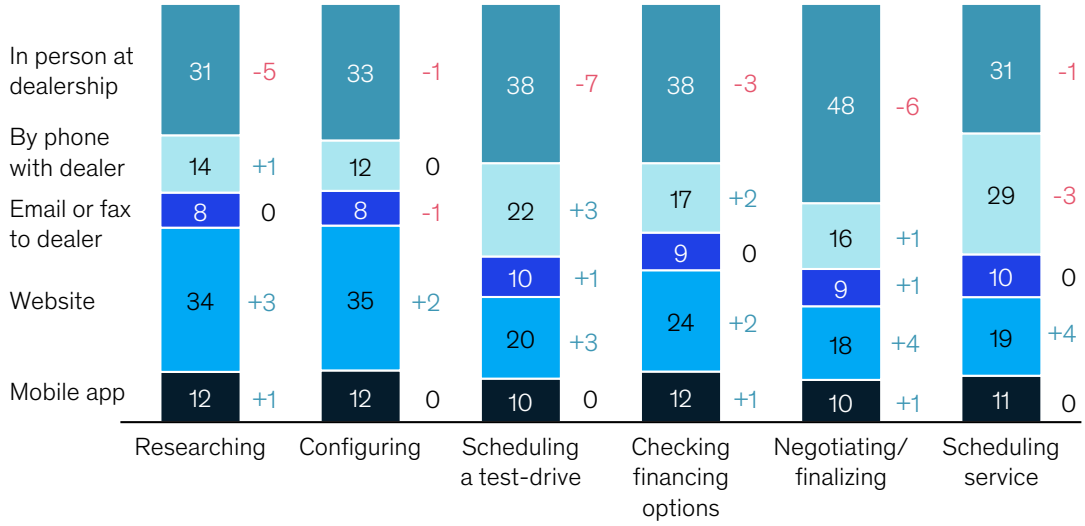
Dealer visits and test drives are still the number one influencing factor for consumers' purchasing decisions today, and around 70% of car buyers still consider the dealership a major touch point to physically experience the car. However, physically experiencing the car will evolve in the future and might also be offered to car buyers in different formats such as test drive centers, home rest drive deliveries or through flexible partnerships such as car rentals for travelers that want to experience their future car for a few days on the road. Thus, the main cause for the slow speed of change is the sheer amount of legacy processes that need to be transformed to fully integrate online and offline. Among these are existing dealer franchise laws, infrastructure development, dealer involvement, and challenges in developing a compelling digital car experience and test-drive alternatives. Changing this model will take time and requires close collaboration between OEMs, dealers, and selected new partners across the retail chain, but our research shows that digital is becoming more important, especially in these times of COVID-19 (Exhibit 3).

Dealership visits and test-drives are still the number one factor influencing consumers' purchasing decisions today, and around 70 percent of car buyers still consider the dealership a major touch point for physically experiencing the car.

Exhibit 3:

Digital is becoming more important along the entire purchasing funnel

Preferred interaction mode for purchasing next car and change from last car purchased[1,2]
Percent of respondents; delta from last vehicle purchase, percentage points

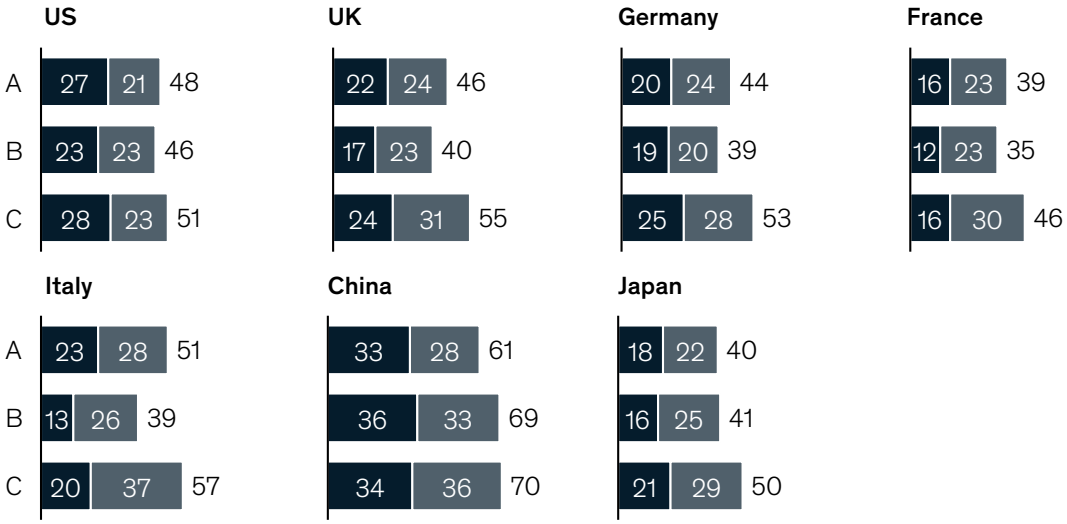


Interest in digital/contactless sales and service[3,4,5]
Percent of respondents; delta from last vehicle purchase, percentage points

A – Online buying: Buying a new vehicle online
B – Contactless sales: Buying a vehicle completely contactlessly
C – Contactless service: Contactless service from dealership or repair shop

Would definitely consider or be very/extremely interested

Would (probably) consider or be interested



1. Q: When you LAST purchased or leased a car/had a car serviced, which of the following sources/channels did you predominately use?
2. Q: For your PLANNED/NEXT vehicle purchase/lease/car service, which of the following sources/channels would you prefer to use?
3. Q: Would you consider purchasing or leasing a new or used vehicle completely online?
4. Q: How interested would you be in the following services?
5. Q: How interested would you be in contactless service options/contactless car sales?

Source: McKinsey Global COVID-19 Automotive Consumer Survey (May 9-17, May 27-29, June 16-18, July 15-17, September 2-4)

1.3 Customers are looking for an adapted dealer role in a new multi-channel landscape

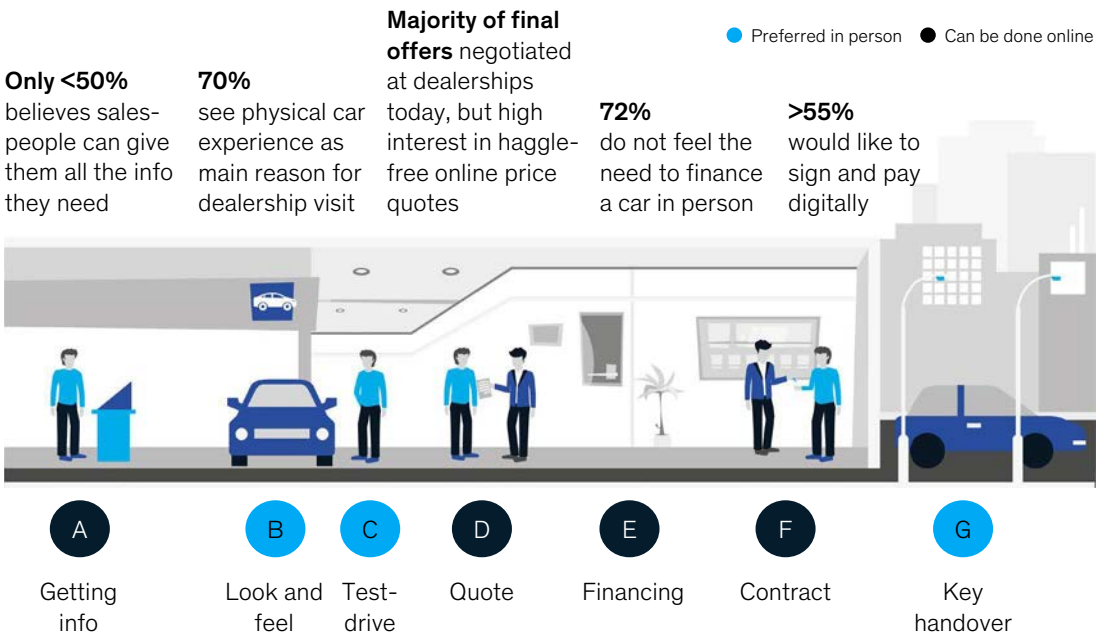
Despite the ongoing importance of the dealership within the car-buying journey, our research shows that around 30 percent of customers today no longer use the dealer or do not see its clear value add. Moreover, most respondents would switch dealers for more convenience or a better price, and around 40 percent say they don't need to see their dealer face to face for repairs – they would be happy to have their car picked up and dropped off. These findings clearly indicate that the role of the dealership needs to change. But on the contrary, more than 40 percent of respondents still agree that the role of the individual sales consultant was decisive in their purchase and would like to stay in close contact with their dealer/car manufacturer after purchase.

To navigate these different perceptions, dealers need an even stronger focus on value-adding activities to stay relevant and establish ever closer relationships with their customers. Investing in enhanced customer analytics, for example, provides the insight and context that allows dealers to better serve customers wherever they are along their car-buying journey. Our research shows that 70 percent of consumers see the ability to physically experience the car as the main reason for a dealership visit. At the same time, less than 50 percent of consumers believe that the sales consultants can give them all the information they need, and 72 percent do not see the need to finance a car in person (Exhibit 4).

When thinking about future car purchases, our research showed that 41% of customers expect dealers to be a superior source of knowledge and product expertise, especially in the areas of connected services, driver-assistance features and

Exhibit 4:

Need for change – the role and business model of the dealership needs to change in the new retail reality to reflect customer preferences and maintain its true value add in the retail chain



The majority of interactions in a dealership today are already replaced or influenced by online. The dealership must systematically reshape its role to maintain its value add in the future sales model

Source: McKinsey Automotive Retail Consumer Survey (US, China, and Germany)

electrification. They also want to be able to access on-site information related to internal combustion engine (ICE) alternatives (e.g., battery EVs and hybrid EVs) and other vehicle technology. This can be achieved either through talking to experts (e.g., product geniuses) or via information terminals that allow customers to access detailed information independently, at their own speed, and in a non-sales environment.

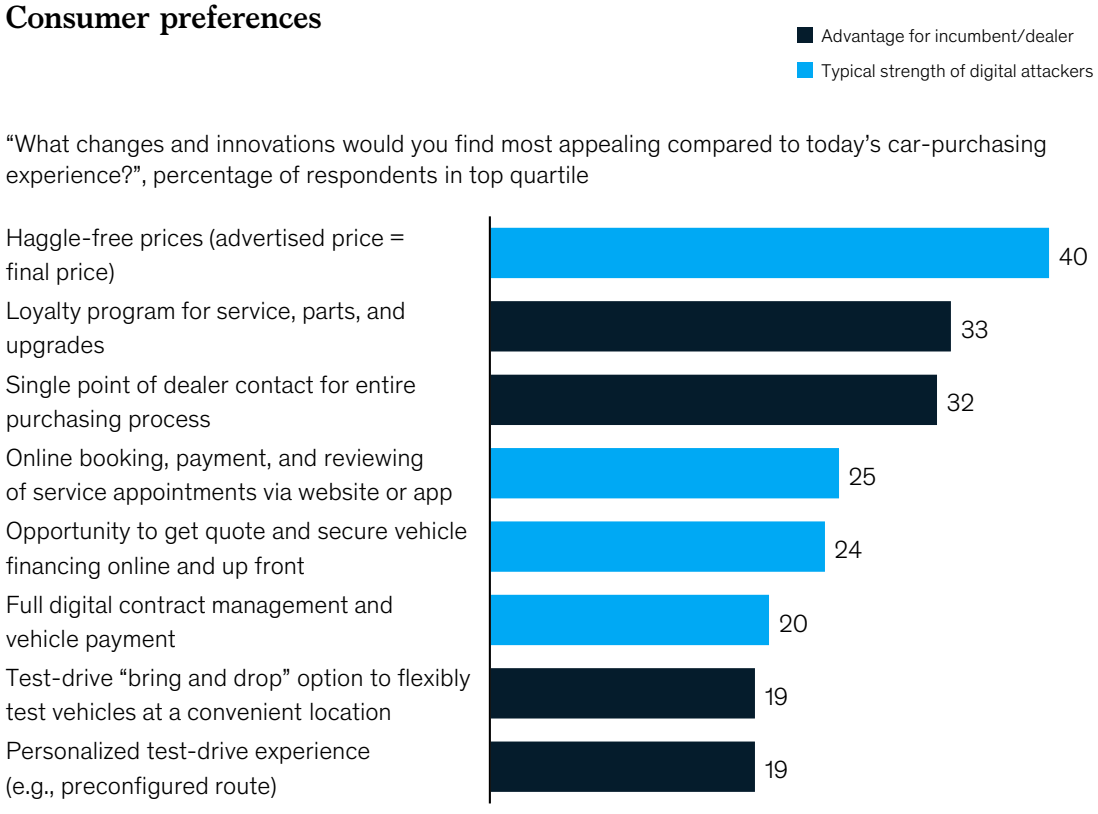
In summary, our research about key elements for the future role of dealerships shows that dealers need to evolve from primary touch points for contract signing and service towards a stronger role as trusted advisors. They should also aim towards becoming no-pressure product experience centers and fully integrating into the broader omnichannel journey.

In addition, car buyers prefer a transparent and stress-free experience – less so the "negotiation process" common at dealerships today and instead more so a transparent form of pricing like they are accustomed to in other industries. In this regard, progress looks like a shift from "black box" pricing to "transparent transaction prices." 40 percent of respondents are strongly in favor of haggle-free pricing, and the majority would like to see the same prices online and offline. In addition, many customers rate the digitization of major steps in the car-buying journey and a single point of dealer contact as very important improvements to enhance the car-buying experience (Exhibit 5).

>90% rate the availability of a tool to facilitate model specification and price comparisons as at least "somewhat important."

Exhibit 5:

Consumer preferences



Source: McKinsey Automotive Retail Consumer Survey (US, China, and Germany)

1.4 Globally, four major and distinctly different groups of car buyers can be identified

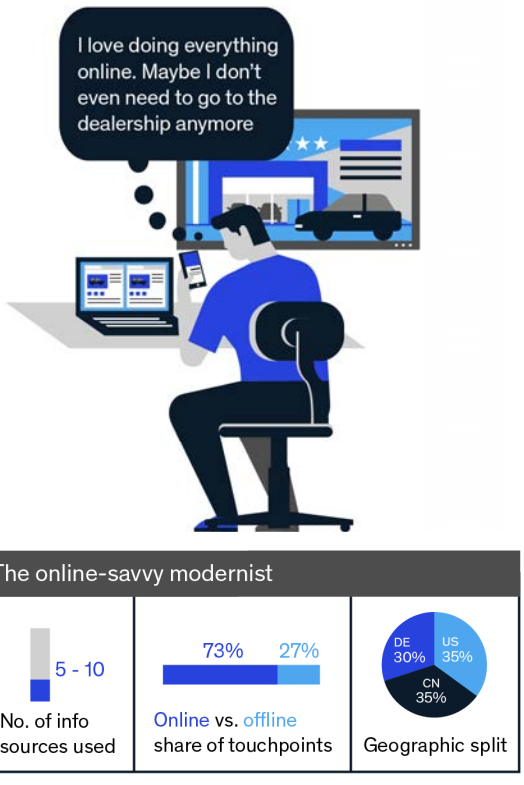
Based on our research, we have identified four distinct groups of car buyers with very different characteristics that exist globally (Exhibit 6). We focused on these groups in Germany, the US, and China. The preferences that characterize these segments lead to a variety of customer journeys and potential touch points that automotive retailers must cater to. In this context, we observe high polarization when it comes to a preference for either innovation or the status quo.

Exhibit 6:

Characterization of core car-buyer archetypes

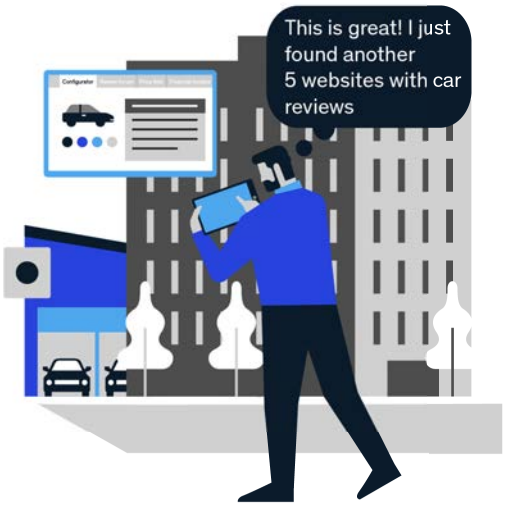
"The hybrid customer"

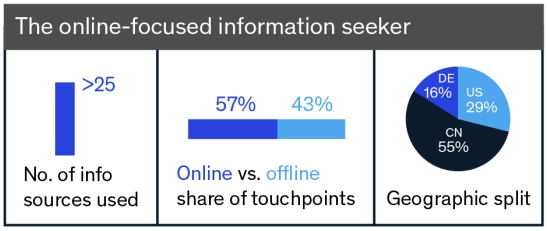
Hybrid customers account for one-third of car buyers and are characterized by an equal mix of offline and online behaviors. They approach dealers for information and testing, but they also make use of online information sources, such as OEM/dealership websites or car comparison portals. On average, their car-buying journey consists of eight to ten different touch points. Hybrid customers tend to live in suburban areas, and seek a casual, knowledgeable, intuitive, and fun buying experience. For gathering information online and the actual purchase process, they prefer the OEM itself over dealerships or third parties; hybrid customers do not heavily rely on traditional dealer structures. COVID-19 circumstances are likely to increase the share of hybrid customers sustainably as familiarization with online channels is accelerating across demographics and further customer groups.



"The online-savvy modernist"

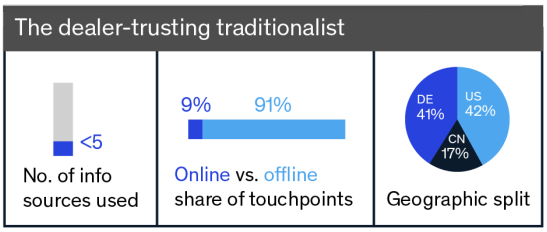
This segment makes up another third of the car-buying population and is equally represented across geographic regions. These customers have a clear online focus with very limited dealer involvement. Such customers not only search online for car information but also strive to complete all other car-buying activities online, such as financing and contract signing. They want a fast and easy car-buying process and consult six to eight different touch points along their journey. Online-savvy modernists are mostly young, tend to live in large or medium-sized cities, and strive for a fast and innovative but predictable buying experience that can be characterized as "easy and everywhere." The majority have already decided on a model before their dealership visit and are largely using the dealer to close the deal. They prefer third parties when gathering information online as well as for the buying process. COVID-19 impact is expected to be moderate as customers are already fully into online channel usage.





"The online-focused information seeker"

Online-focused information seekers account for 15 to 20 percent of the researched population and are particularly well represented in China. They are characterized by a clear online focus during the information-seeking phase, but they seek consultations with dealers throughout the whole car-buying process. Their strong need for information is reflected by more than 25 different touch points throughout the journey. Online-focused information seekers are fairly young, live in larger cities, tend to buy premium vehicles, drive longer distances, and enjoy a unique, cutting-edge, and innovative buying experience. Despite their online affinity during the research phase, they want to stay in touch with their local dealer after purchase. Like hybrid customers, they prefer having the OEM itself as their online partner for information as well as during the buying process. Covid-19 impact is expected to be limited as customers are real car enthusiasts that heavily have been using online channels already for their search and can now easily leverage contactless and remote buying services of their local dealers.



"The dealer-trusting traditionalist"

This customer type accounts for around 20 percent of all car buyers, made up mostly of the older population in the US and Germany. These customers view the dealer as both their key source of information and a partner throughout the car-buying process. They engage an average of only five touch points throughout their journey. These customers are reluctant to go online and are very loyal to their local dealership. Dealer-trusting traditionalists tend to be older, live in the suburbs, drive fairly short distances, and strive for a personalized, high-touch buying experience. If at all willing to buy online in the future, they would prefer their dealer to be their online partner for information as well for the buying process. Dealer-trusting traditionalists are potentially affected in two ways by current COVID-19 circumstances: they must either adapt to using online channels (thereby becoming part of another customer segment) or temporarily pause their purchasing activities.

While the four groups of car buyers exist globally, there are several significant differences among them in the three countries – above all in China (Textbox 5).

Textbox 5:
Key characteristics of car buyers in China, Germany, and the US

China

In China, the share of "online-focused information seekers" is particularly strong – and together with "online-savvy modernists," accounts for over 55 percent of the total population surveyed. However, within those online-inclined customer groups, the share of online sources is on aveage 10 percentage points lower compared to Germany and the US.

"Online-focused information seekers" have a closer relationship to the dealer than in the other markets and have the highest satisfaction rates across all touch points. Compared to Germany and the US, this customer group has high loyalty, also in aftersales phase, and customers are equally present in the premium and volume segments.

"Online-savvy modernists" are happier with their dealership in China than they are in Germany or the US, and China is the only market where customer satisfaction actually increases in the purchase phase.

However, overall, "hybrid customers" are still the largest group in China – they are less loyal to their dealers than they are in other markets. They have the lowest score for "would like to stay in touch with their dealer," and the highest score for "use independent repair shops."

Germany

Both the composition of customer groups and customers within those groups lean towards traditional themes and are slower to adapt to innovation and change compared to China and the US.

Germany has the lowest share of "online-focused information seekers" and the highest share of "dealer-trusting traditionalists" compared to China and the US.

Within "dealer-trusting traditionalists," customers are even more loyal to their specific dealer and their specific brand compared to other markets. For example, they have the lowest share of online touch points along their journey (7 percent in Germany versus 8 percent in China, and 12 percent in the US), the highest score for "option to meet dealer" in the online sales process, and the lowest scores for "would go to a different dealership for convenience" and "would switch brands for a personalized experience."

US

The composition of customer groups is rather traditional; for example, there is still a large share of "dealer-trusting traditionalists" – but customers within those traditional groups are up for change.

The US has the highest relative share of using online sources within each customer group, even though customer group composition does not lean so much towards "online" like in China; for example, across customer groups, the US has the highest share of "had already decided on model before dealership visit" and the highest score in "would switch brands for a personalized experience."

2 Cost pressure fueled by ACES trends and digitization is accelerating the retail model transformation

The ACES trends (autonomous driving, connectivity, electrification, shared mobility), a growing shift towards online sales, and omnichannel buying will have a major impact on the automotive retail landscape as we know it. COVID-19 is further accelerating those trends that were already underway but had not yet been widely adopted – these will likely become the new normal. While we see diverging expectations towards the speed of change, most players acknowledge that they need to prepare now. As an early sign of this, we observe many players increasingly experimenting with different retail formats, testing online sales channels in selected countries, or piloting direct sales models. Regarding automotive retail, we will discuss four of these trends in more detail, which are online and direct sales, shared mobility, connectivity, and electrification (Exhibit 7).

Exhibit 7:

The business model has to adapt to compensate for retail trends

Indicative

Impact of trends on dealers – "do nothing"

	2020	2030	Trend impact end state, 2030
Online and direct sales			
New	↗	↘	Reduced volumes, handling fees, and margins
Used	→	↘	Pricing and offering transparency
Aftersales	→	→	Pricing and offering transparency
F&I[1]	→	→	Increased finance penetration, but partly from 3rd parties
Cost	↘	↗	Digital back office
Shared mobility			
New	↗	↘	Reduced demand for car ownership
Used	↗	↘	Fewer private units in operation
Aftersales	↗	↘	Professionalized fleet services
F&I	↗	↘	New revenue streams: subscription services
Connectivity			
New	→	→	Better CRM and end-of-term lease management
Used	→	→	–
Aftersales	↗	↘	Less body repair work, more expensive parts
F&I	↗	↘	New income via connected services likely to go mostly to OEMs
Electrification			
Aftersales	↗	↘	Longer maintenance cycles, less maintenance parts and services
Cost	↘	↘	Parallel ICE/EV competence drive costs

OEMs and dealer groups need to take a strong role to lead and coordinate the transformation while also reinventing themselves

1 Finance and insurance

Source: McKinsey Automotive Retail Practice

Online and direct sales

Initial signs of online sales picking up speed in line with shifting consumer preferences are closely monitored across the entire automotive sales ecosystem given the potential impact on dealers' already slim margins. At the same time, OEMs face high dependency on their existing networks, which forces all players to make conscious and integrated decisions to shape the future now, as the status quo becomes more and more challenging.

Implications

For OEMs:
Online sales enable OEMs to reduce their distribution costs and provide more direct access to the customer. In addition, online sales allow for better steering of transaction prices end to end, which might well prove to be the true game changer in an industry that is still spending 10 to 20 percent of its overall revenue on incentives. On the contrary, OEMs still rely heavily on their networks' ability to smooth out fluctuations in demand and absorb on-top volumes in quarter-end/year-end whole-sale pushes and are still willing to tie up huge amounts of capital in physical outlets and vehicle stock. For these reasons, a balanced solution must be defined – potentially also dependent on regional differences.

For dealers:
Given consumer preferences and the benefits for OEMs, dealership volumes will be affected in the medium to long term for both new- and used-car sales. Depending on individual dealership size or dealer group strategy, partnering with OEMs or establishing their own online channels and closely connecting their physical and online presence will become more important. Additionally, the dealership network will maintain its importance for offline touch points throughout the customer journey. In turn, this allows dealers to charge for fulfillment and aftersales activities. Proving excellence in fulfillment and aftersales activities will be crucial for negotiating fees with OEMs.

For customers:
E-commerce in automotive retail fundamentally changes current purchasing behavior, allowing car buying "with just a click" and increased transparency on vehicle pricing and vehicle availability. While addressing the key customer pain points of negotiating a final price, securing vehicle financing, or choosing add-ons, paperless signing is still perceived as a hurdle for over 50 percent of customers. If implemented well, customers can benefit from higher transparency and comparability as well as professionalized dealership organizations.

Shared mobility

The continuing and increasing trend towards shared mobility impacts the automotive retail industry in several fundamental ways: Shared mobility requires a change in vehicle type (e.g., multipurpose vehicles) and a change in the type of offering (e.g., OEMs as mobility service providers). In the longer term, shared mobility will likely also lead to slower growth in the new private-car business. However, through at least 2030, expected growth for new private-car sales will still outpace the total impact of shared mobility.

Implications

For OEMs:
Addressing and actively embracing shared mobility as a rising business opportunity beyond traditional retail also means developing various offering strategies that not only differ by region but also by country and even by city in order to account for mobility demand differences in rural and urban areas. As the playing field is still rather embryonic, OEMs are additionally faced with a multiplicity of new ventures and a huge variety of innovative offering models. Finding a balance of in-house offerings and local partnering will be key to comprehensive success.

For dealers:
Fleets of independent shared-mobility providers will largely be sourced directly from OEMs and, as such, cause a negative effect on dealers' new-car sales. Moreover, shared mobility will negatively impact the dealers' aftersales business as mobility service providers (OEM-owned and independent) gain more negotiation power and can move sizeable volumes from one dealer to another, which will put pressure on margins. However, the impact on dealers will, to some extent, depend on geographic location. As large dealer groups do business in rural and urban areas and across borders, they will need to transform themselves into mobility service providers, working in collaboration with OEMs or establish their own alternative mobility offerings.

For customers:
Depending on the region, many customers today already experience a variety of shared mobility offerings. In both China and the US, the e-hailing market is monopolized by one or two players, whereas the European market is highly fragmented, with offerings from both OEMs and new ventures – partially due to different legal structures in Europe. Since OEMs and dealers need to move in various directions to fulfill varying demands, new private-car customers can also expect an increasing portfolio of mobility offerings, e.g., subscription models or turnkey solutions.

Connectivity

Today, less than 20 percent of vehicles on the road are equipped with integrated connectivity services, and associated business models have not yet developed as expected. However, the importance of a connected road network for vehicles has been growing continuously and the percentage of consumers ready and willing to change car brands for better connectivity has also doubled over the past few years to around 40 percent today.

Implications

For OEMs:

A large share of new vehicles sold provide some kind of connectivity. In the premium segment, the majority of automotive manufacturers have already installed fully connected infotainment systems in all their new vehicles. However, bringing a high level of connectivity to mass-market vehicles will require greater cooperation between OEMs and telecom providers. The latter need to offer their infrastructure and licensed spectrum, and OEMs and suppliers need to create the hardware compatible with the technology. The value chain is transforming into an ecosystem where the relationships between the actors are still uncertain.

For dealers:

Dealers mainly profit from connectivity in three ways: participation in connected services revenues, additional insights on driving behaviors, and an increased transparency into maintenance needs through connected vehicle sensors. However, to benefit dealers often must partner with their OEMs that typically control the access to the required data.

For customers:

Already today, owners of full-fledged onboard infotainment systems enjoy features like suggestions for nearby consumer facilities (e.g., restaurants, hotels) or adaptive navigation systems. With an increasing share of vehicles being part of a larger telecom infrastructure, new services can arise and uncover further benefits (e.g., free parking spot or optimized route guidance).

Electrification

The percentage of vehicles sold with electric drivetrains today is around 3% globally, but given technological advancements and tightening CO2 regulations the industry aspires to launch over 400 new electric vehicle models until 2025. The magnitude of this supply-side shift is expected to at least triple global electric vehicle sales within the next two to three years making it a key topic for automotive retailers in many countries worldwide.

Implications

For OEMs:

OEMs themselves are facing huge investment needs for vehicle electrification combined with EV margins that are not expected to achieve the current margin level of ICEs anytime soon. Thus, OEMs are scrutinizing all major cost buckets for savings potential including adaptations to their current sales model. In addition, automakers are under high pressure to meet their electric vehicle sales targets to avoid penalties from tightening CO2 regulations.

For dealers:

Aftersales revenues and profits will come under big pressure, as EVs have fewer moving parts and need less maintenance. For example, oil changes are currently a huge profit driver that will ultimately dissolve for dealerships. In the medium term, dealers will additionally face the complexity and cost of handling sales and service for both EVs and ICEs.

For customers:

Recent announcements and portfolio perspectives disclose a large upcoming variety of EVs across premium and mass-market brands. As competition for EVs is steadily growing, customers can expect EV prices to become competitive with ICE prices sooner rather than later. Already today, price levels in China for mass-market EVs and ICEs have equalized. As the EV driving experience fundamentally differs from the ICE experience and might not be associated with any particular brand, customers at the beginning will likely be faced with a significant selection complexity when shopping for EVs.

3 Five future retail-model archetypes and their implications for OEMs and dealers

Staying ahead of the current disruptions in automotive retail will require more of OEMs than simply moving their operations online. The rise in car buyers' service expectations and the growing diversity of their preferences, plus the nonlinear speed of change triggered by the ACES trends, increase the difficulty for OEMs and dealers to transform their retail model.

Considering this, our research indicates that OEMs' strategies for the future need to become much more diverse and will diverge from the current retail model to an extent not seen before. We also observe a high ambivalence among many players: On the one hand, all players feel the need to act fast due to the long implementation times of any network-related changes as well as the distinct differentiation potential that the right move offers on both the cost and customer experience side. On the other hand, many OEMs struggle with taking bold, strategic steps into the unknown in a situation where many of the trends still feel new. The number of new retail formats is an example of the high level of experimentation.

To provide a comprehensive perspective on the strategic options that OEMs can consider in their strategic road mapping, we have developed a set of five archetypes of future retail strategies: 1) OEM building on dealer as entrepreneur, 2) Dealer as execution agent, OEM in control of new-car sales, 3) OEM fostering competition, dealer as exchangeable execution provider, 4) OEM owning retail, and 5) OEM handing over to importer. These archetypes were derived based on in-depth research and many discussions with leading players on their own future retail strategies and therefore represent a comprehensive synthesis of the current state of thinking.

It is also the case that a combination of approaches may be best for any given OEM or dealer. Specifically, a region-by-region and brand-by-brand approach to a future retail strategy means that a single OEM or dealer may adopt two or more of the archetypes defined above. Our research highlights the different nature of automotive markets in terms of maturity regarding ACES trends, legislation for direct sales, and affinity for online sales – and these determine not only the speed, but also the direction of change. But OEMs' market positions also differ strongly by region, as do the ecosystems they have built. Taking this into account for any strategic decision will be key for success and therefore requires a regional approach instead of a global one.

As current circumstances due to Covid-19 are accelerating relevant trends (e.g., significantly increased online activities), the need to rethink retail strategies becomes even more prevalent and timely piloting the one or another approach will be crucial.

Exhibit 8:

OEM building on dealer as entrepreneur

3.1 OEM building on dealer as entrepreneur

The "dealer as entrepreneur" strategy (Exhibit 8) aims to keep the dealer as a key element in the overall retail network while introducing an online direct sales channel alongside it. To help the network offset the negative impact of volumes shifting online, both dealers' top and bottom lines need to be strengthened – through pulling a range of opex and capex levers and sharing future upside potentials through, for example, new revenue streams like over-the-air updates among the partners. In order to achieve this, three steps need to be taken:

a) Differentiate physical formats: Reducing physical footprint costs is key for dealers in a scenario that channels more than 10 percent of sales towards the OEM directly. While this appears to be an "old" topic in an industry that has experimented with new sales formats for the past ten or more years, we believe that this model still holds potential. For it to be successful, a shift of focus is needed from OEM-run, mostly expensive flagship formats (e.g., experience centers) to lean and efficient, mostly dealer-run formats (e.g., service factories, pop-up stores, and small city stores) to attract new customer groups.

b) Drive network consolidation: For this to be successful, the overall network needs to show a high degree of (owner) consolidation, as size and the ability to manage entire and coherent areas become critical requirements for dealers to fully leverage the advantages of differentiated formats, for example.

c) Establish clean-sheet dealer processes: To further reduce running costs for dealers, OEMs and dealers together need to pull all available levers to streamline processes and lower administrative burdens – e.g., through unlocking the potential of "digital dealership," integrating systems further (across ordering systems, online configurators, and wholesale/retail CRMs), and focusing steering on results instead of processes.

Prerequisites

This approach builds on a strong market position that allows for dense physical coverage even with a sizeable amount of volume moving online. Furthermore, it requires that dealers, who manage multiple outlets, have sufficient firepower to take the necessary investments in the future. In addition, it is essential to establish a clear commercial and governance model that allows dealers to participate in the online direct sales to align incentives across online and offline.

Implications

For OEMs:

The key objective of this strategy is to strengthen and sustain the dealer network, while at the same time, take advantage of an online direct sales channel. Thus, it will put the OEM in a strong position to steer transaction prices to reduce incentive spend by, for example, adjusting tactical campaigns quickly based on early indicators from online sales. Additionally, it opens opportunities to save resources in network management and steering, as fewer but more professional partners are taken care of.

For dealers:

For strong dealer groups, unlocking the full potential of opex and capex reduction will be a key success factor. At the same time, increasing their profit share in other business areas such as service and used cars will be critically important. For large dealer groups, which have the ability and investment power to take responsibility for entire areas, this strategic option will be an opportunity to grow and gain influence. Smaller dealerships might only remain viable in rural, sparsely populated areas.

For customers:

This strategy is set up for delivering an enjoyable and truly omnichannel customer experience. For example, it can allow customers to easily get in touch with the brand online or via other specialized channels, and ensure a pressure-free experience with transparent pricing across the entire network. However, to achieve this, both the OEM and dealer need to ensure seamless integration of their respective activities for customers as well as coordination within a network of differentiated channels.

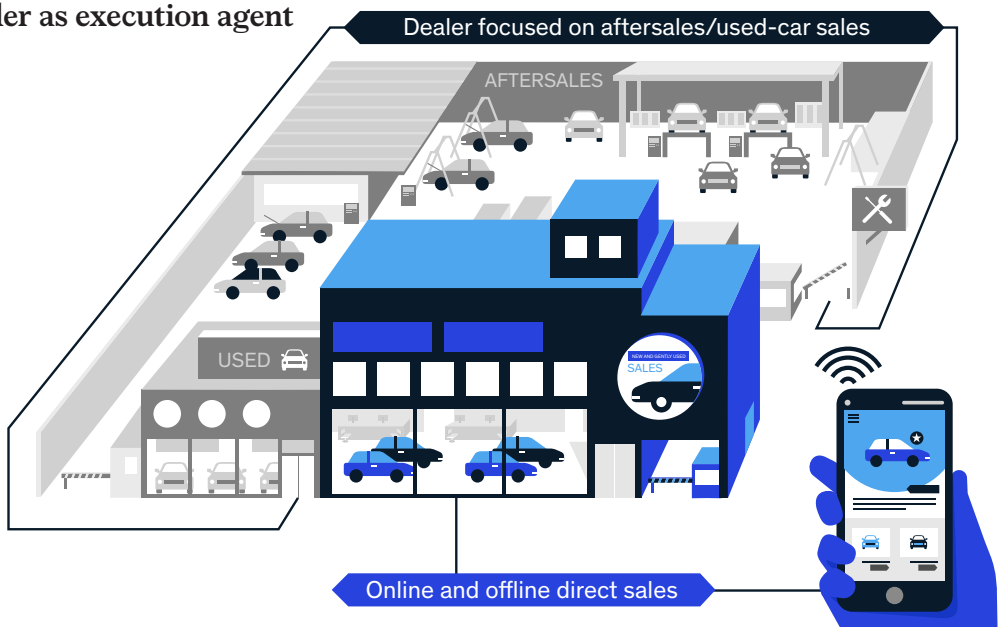
This approach builds on a strong market position that allows for dense physical coverage even with a sizeable amount of volume moving online.

3.2 Dealer as execution agent, OEM in control of new-car sales

The "dealer as execution agent" approach (Exhibit 9) sees the OEM taking full control of the new-car-sales side – while building on the existing dealership network. The dealer is transformed into an agent for the sales process, with the OEM effectively taking over new-car sales end to end, including stock holding and transaction pricing. The dealer, in turn, only fulfills the transaction based on directions set by the OEM and receives a fixed handling fee for this instead of a share of the revenue. With this approach, the OEM is going in the opposite direction as compared to the first archetype: limiting the dealer's role as entrepreneur and driving the system more centrally instead.

Exhibit 9:

Dealer as execution agent



Prerequisites

This approach is viable especially in more fragmented networks, where direct customer access for OEMs is key, online sales will make up a considerable share of new car transactions and dealers lack the scale to truly transform their business by leveraging different physical formats. Given the shift from a wholesale to a retail model, OEMs will also need to have or establish alternative (direct) channels, such as rental and fleet businesses, in order to maintain their ability to capture on-top volumes in the market to avoid piling up stock in volatile markets.

However, given the large transformation of the dealership's role from an independent business with slim margins but high degrees of freedom into an agent dependent on the OEM and working on stable income streams with limited up-/downside potential, this approach will likely see at scale implementation times of over five years.

Implications

For OEMs:

While this model allows OEMs to closely integrate the online and offline worlds and steer transaction prices end to end across channels, it also requires them to invest a substantial amount. This is largely because of what is needed to take over the additional capital requirements of new-car sales – including responsibility for stock holding, tactical wholesale push activities, and balancing of demand peaks.

For dealers:

In this archetype, dealers are focused on used-car sales and service and are thus unburdened from the inherent risks of new-car sales. However, they also see their role changing considerably, as they lose their ability to differentiate themselves through pricing, thus becoming even more dependent on the OEMs. This model provides dealers more stable, yet overall lower returns and requires dealers to further downsize as well as to increase operational efficiencies. In addition, it could change the way how capital markets value dealers – making it especially difficult for larger dealer groups to justify this move to their investors.

For customers:

This approach provides a truly seamless customer journey built around an integrated customer interaction model with consistent and haggle-free offers both online and offline. However, it remains to be seen whether dealers' engagement and willingness to excite customers in new-car sales will be lower if they are reduced to mere agents.

3.3 OEM fostering competition, dealer as exchangeable execution provider

Even more radically, the "dealer as exchangeable execution provider" strategy (Exhibit 10) aims to reset OEMs' dependency on their dealership networks by building a strong online direct sales channel, complemented by a set of alternative players for each of the remaining physical touch points along the customer journey. This may include leveraging rental companies for test-drives, delivering vehicles ordered online, certifying third-party repair shops to also maintain healthy competition in the service business, or even selling cars and mobility options through non-industry brokers, such as banks or insurance companies, offering a stationary network for handling fees.

Exhibit 10:

OEMs driving competition and partnering with selected 3rd parties

Prerequisites

This model is tailored to markets with a high possible share of direct online transactions where physical touch points play largely a complementary role to support the online sales process and aftersales services can be offered by independent partners. To be successful, OEMs need to diligently prepare alternatives early on – as dealers will likely take decisive actions to defend their business or change the franchise as soon as they are confronted with the new realities. Having their own strong retail presence may help mitigate the downsides and risks of such a transformation. Finally, the customer value proposition across the different touch points needs to reflect the overall positioning of the brand and is therefore likely to be more fitting for volume brands. Alternatively, this model can also be leveraged as a quick way of entering new markets without an existing dealership network in place to complement a strong online sales channel.

Implications

For OEMs:

While this model vastly increases OEMs' ability to steer the network and slash costs through enforced competition, it also deprives them of the ability to leverage their networks for wholesale activities. The loss of this lever effectively forces OEMs to move additional volumes into other channels, such as fleet or rental, or move entirely from a push to a pull (only) model. It also enables OEMs to quickly enter new markets in a lean and cost-efficient way – without building a network of franchise dealers first. In order to succeed, however, OEMs need to have a clear focus on profitability in addition to volumes to remain attractive as franchises for their partners and develop strong coordination skills to successfully manage a broad network of diverse partners.

For dealers:
This model is effectively the ultimate stress test. Dealers either hand back their franchise or transform it radically into a cost-efficient service provider that stays competitive against specialized players, such as rental companies or independent aftermarket players.

For customers:
This approach, centered around online sales, offers customers a low-cost, no-frills experience with low transaction prices and a clear value-for-money proposition. The customer journey will be based on one integrated digital backbone, enabling seamless navigation of a journey with multiple players along individual touch points.

3.4 OEM owning retail

The "OEM owning retail" approach integrates all retail activities into the hand of the OEM and implies the highest level of control and customer access, but also high investment needs in its own physical outlets. While we see traditional OEMs moving away from their own retail activities, new players like Tesla or NIO are leveraging this approach to build a lean and asset-light network of highly differentiated physical stores around an online backbone.

Prerequisites
In the short term, this model is primarily viable for new players with no existing network structures or traditional players entering new markets.

Implications
For OEMs:
This model requires OEMs to make heavy investments into brick-and-mortar retail locations. To make this feasible, they will need to grow online sales quickly in order to reduce the capex requirements of building and running a dense network of physical outlets.

For customers:
If managed successfully, this approach could enable a distinctive and seamless experience for customers – in turn, putting OEMs in the perfect position to gradually move to an online-only sales model. Additionally, fully owned sales and service formats provide a more tailored or even personalized experience for customers.

3.5 OEM handing over to importer

The "handing over to importer" model is the opposite approach of "OEM owning retail." Here, the OEM moves out of local retail and wholesale activities, handing them over to a professional partner instead. The importer, which is typically comprised of large dealer groups, steps up and manages the entire country or region end to end, within the boundaries of the agreement reached with the OEM.

Prerequisites
This model is mainly relevant for smaller markets, such as the Baltics. Alternatively, it provides an opportunity for OEMs with subcritical market shares in large markets to retain their presence at minimum fixed costs.

Implications
For OEMs:
In light of the increasing complexity of the automotive sales and service ecosystem, this model enables OEMs to focus on fewer markets and, at the same time, maintain professional management of non-core markets. However, it also deprives OEMs of the ability to adapt to short-term demand fluctuations by moving volumes between markets, as importers will demand high discounts for any on-top volumes.

For dealers:
For large dealer groups, this model is highly attractive as it offers them stable margins at scale, without engaging in a dealer-by-dealer fight for incremental profit. This approach also allows them to capitalize on their core strength: a high degree of professionalism in delivering sales and service. We are already seeing large dealer groups actively seeking to engage strongly in this type of business.

For customers:
In this model, the customer moves further away from the OEM, with the importer acting as an additional intermediary. However, this will likely not be perceived as a large change from an end-consumer perspective.

Each archetype offers a distinct set of principles, prerequisites, and implications, but it is also the case that a combination of approaches may be best for any given OEM or dealer. Specifically, a region-by-region and brand-by-brand approach to a future retail strategy means that a single OEM or dealer may adopt two or more of the archetypes defined above, depending on the wide-ranging nature of automotive markets in terms of maturity regarding ACES trends, dealer franchise legislations, and affinity for online sales. Additionally, OEMs' market positions vary widely by region, and so do the ecosystems they have built. Taking this into account for any strategic decision will be key to success and therefore requires a regional instead of a global approach.

4 Outlook – getting started with the automotive retail transformation

We see a clear shift away from the current sales model with opaque pricing and complicated offerings towards a new expertise-driven retail model where advice, experience, and transactional transparency for customers are the main foci.

For OEMs and dealers, the specific strategic decision regarding which archetype to pursue to address this shift will vary according to each organization's starting point, but the decision will likely determine the future success of the entire company; any step in the wrong direction will be difficult or even impossible to correct.

Textbox 6:
Interview with Adam Stewart, Google VP of Automotive, Consumer Goods, Government, and Entertainment

Big data and advanced analytics will offer new opportunities for auto retail in the future. Which exciting use cases do you see/are you currently working on?
We're shifting from a mobile-first world to an automated first world. If you take medical care as an example, the concept of a primary family doctor was substituted by specialized clinics and hospitals, and through that, patient information and history became fractured and incomplete. Today, healthcare start-ups are taking a giant leap forward in bridging this gap in patient data, providing a singular view of a patient's health history to conduct all sorts of interesting things from DNA sequencing to disease prevention.

If you link this to the auto industry, it used to be that local brand marketing drove us to our trusted dealership to buy a car. Today, consumers are driving their own unique purchase journeys across multiple channels. That innate understanding dealers had about the customer is being replaced with questions about what really drives our customers' purchase decisions. As I shared earlier, customer data lives across different tiers and silos, but as brands start to connect their data, they can then rely on machine learning to recognize patterns in the data, predict intent, and create more helpful, seamless customer experiences. This will be critical for the auto industry in order for it to compete with more nimble start-ups and tech companies that already have a holistic view of the customer from research, to consideration, to purchase.

At Google, we're helping auto marketers utilize machine learning to work faster, work smarter, and drive more efficiencies in their marketing. For example, our machines can take customer signals – such as time of day, device, or previous searches – and apply those signals to a customer's next touch point, such as watching a video on YouTube.

What is your perspective on e-commerce with regard to automotive? Will we buy cars online in the future? What would this look like?
While some car purchases will shift online – there are models that already exist – that doesn't mean the dealer experience will disappear. Similar to how traditional retailers, like Best Buy, have had to rethink their business models as transactions have moved online, dealers will need to evolve their offerings as well. They'll have to find ways to add value to the overall customer shopping journey by creating more personalized experiences and by making it easier for the customer to get the information he or she needs. This shift will likely result in more partnerships between auto brands and tech companies as brands increasingly rely on native digital players to help them build more seamless customer experiences.

How do you see the future role of the dealer in automotive? And what role will Google play in auto retail?
Dealers will continue to play a significant role in the auto industry for years to come; however, the most successful brands will be those that figure out how to connect their data across tiers by establishing close partnerships. Google must continue to connect dealers to the right customers in the right moments through machine learning, as well as help dealers understand the true value of their marketing by tying it back to business results (i.e., store visits and eventually store sales).

While the details of the approach will vary between brand and region, what is clear across the board is that inaction is not an option. Any hesitation to move forward at all – i.e., a decision to maintain the status quo – will be equally dangerous. COVID-19 is accelerating the transformation, changing consumers' buying behavior and openness to online sales, while at the same time revealing the weaknesses of today's sales model, including the need to significantly reduce costs. Thus, a commitment to retail innovation is a must, and the time to act is now. No matter where they are today – along the automotive value chain or around the world – all OEMs and dealers can take immediate action in five areas to move their retail models forward:

Define strategic focus areas and create alignment within the organization

Before moving ahead, automotive OEMs need to decide on their future offering a retail model best suited to each brand and each region. Setting such strategic guardrails is essential for a successful transformation and provides a clear future direction for the entire organization as well as the ecosystem of partners. Only such clarity will allow them to properly define future roles, to effectively allocate investments, and to build new capabilities required for a successful implementation.

Investigate direct and online sales models

As outlined in the introduction of this article, several OEMs are establishing or expanding direct-to-consumer sales. Each of those OEMs is taking on new responsibilities and shifting its sales model from wholesale to retail. This often includes direct pricing, stock handling, and better customer access. Retail partners often remain involved, but in a new role as "agents" that receive a commission or handling fee for providing certain services. Additionally, nearly all major OEMs are running online sales pilots. Some include dealer involvement, some do not, but all are trying to test the consumer's appetite for online sales as a more direct and cost-effective form of sales. COVID-19 is accelerating the shift to online sales and requires OEMs and dealers to not only invest in the required infrastructure, but to more fundamentally align on the role of online sales as a key channel in the future sales model.

Consider transaction-price steering as a true game changer

Driven by consumer preferences, several OEMs are experimenting with haggle-free transaction prices both online and offline. Prominent examples are larger dealer groups such as Sonic Automotive, or premium brands like Lexus, where more than 10 percent of its US volume is sold at transparent prices under the Lexus Plus program. For online and direct sales models, pricing becomes an essential piece for steering omnichannel competition as well as retail volumes and requires new in-house capabilities and analytical approaches for OEMs, both in their headquarters and national sales companies.

Define measures and leaner formats to reduce retail costs

Establish a cross-functional team and cooperate with dealers to identify measures to reduce retail costs in terms of dealer standards, owner consolidation, and digitally enabled sales and new store concepts (e.g., experience centers and city stores) to complement traditional dealerships. Enhance the integration of offline and online channels into an omnichannel journey, where the offline vehicle experience and ordering are directly linked to one digital backbone that creates efficiencies and allows for a more personalized customer interaction.

Build the necessary capabilities and adapt the organization

Establish new roles in the sales process, such as product geniuses at dealerships, to create a simplified and pressure-free car-buying experience with deep product know-how, especially on EVs and connectivity. In addition, build up new capabilities for your online sales channel and country organizations that support a more customer-centric and direct sales process (e.g., lead management and pricing) and adapt roles and responsibilities accordingly to the new sales model approach.

Get started with the automotive retail transformation now

Develop your automotive retail strategy based on a region-by-region and brand-by-brand approach instead of a one-size-fits-all model. The retail strategy may represent one of the five archetypes or be a

Buckle up – the time for a disruptive change in automotive retail is now!

combination based on the different natures of automotive markets (maturity of ACES trends, legislation for direct sales, affinity for online sales, the OEM's respective market position, etc.). Customize your retail strategy jointly with value chain partners, e.g., large dealer groups, individual outlets, or importers. Develop joint business cases, e.g., using digital solutions and advanced analytics to double down on customer-centric and multichannel journeys, serve a wide range of individual customer preferences, and enable seamless information sharing between channels and retail partners.

Eventually, roll up your sleeves and get started – align on a clear strategy and launch dedicated pilot projects to accelerate the end-to-end implementation in a specific region or market together with your most important retail partners. Buckle up – the time for a disruptive change in automotive retail is now!

Leaving the niche: Seven steps for a successful go-to-market model for electric vehicles

To regain momentum after the COVID-19 pandemic ends, the players in this market must reconsider their strategies.

June 2020

by Sebastian Kempf, Philipp Lühr, Patrick Schaufuss, Anna Strigel, and Andreas Tschiesner

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To date, electric vehicles (EVs) have been niche products, so many OEMs have focused their go-to-market (GTM) strategies on a small, tech-savvy segment of automobile customers. Then, just as electric mobility was about to take off and sales were accelerating in several markets around the world, COVID-19 struck.

There are many questions about how the coronavirus could affect the global EV market. The answer will vary by region. Regulation and consumer incentives drive China's EV market, and the central government extended purchase subsidies by two years in March 2020. In Europe, regulators and industry stakeholders lean toward incentives that would favor clean powertrains. EU member states are also expected to maintain the 95-gram CO_2 fleet-emission target from 2020 through 2021, though it will affect the number of vehicles sold. The US automotive market—probably the hardest hit—will require some time to recover: EV sales may stagnate for one or two years before consumer confidence recovers and people are willing to pay for EVs. One big factor in the delay is record-low oil prices, which have widely eliminated the advantage EVs had for total costs of ownership.

Now more than ever, a radically new GTM approach is required to win consumer support for EVs, since COVID-19 could fundamentally influence the attitudes of consumers toward mobility. If they have recently experienced clean air in cities, will that make them lean toward EVs? What's more, a majority of the population is now getting used to online shopping. Will that make consumers more likely to consider buying cars online? And since people now have to avoid crowded spaces, will individual mobility increase after the pandemic ends? Finally, some consumers are avoiding gas stations. Will the ability to charge at home become a purchase consideration for EVs?

Although such questions are difficult to answer, consumers may be more reluctant than ever before to make big purchases, such as cars. Yet the increased public focus on climate change, shifting environmental regulations, and technological advances are making the case for a green-mobility transition and thus for EVs. First, however, the current GTM approach must change, and that will require both OEMs and their partners in the EV ecosystem to change as well.

The challenges ahead

Many challenges for the growth of the EV market lie ahead, but some stand out. In particular, a scalable GTM model for EVs must address new regulations that may influence competition, the customer base, infrastructure, and the business case for and profitability of these vehicles (Exhibit 1).

The regulatory environment

In reaction to increasingly tight CO_2 regulations and the anticipated sizable penalties for noncompliance, most automotive players have ambitious EV-growth plans: OEMs have announced the launch of more than 600 new EV models by 2025,[1] and competition will probably grow as many new players enter the market. Increasing sales of new EVs will be a complex challenge, and OEMs may find it more difficult to make profits if governments reduce subsidies as EV technology advances.

Customers

Our 2019 EV Consumer Survey shows persistent hesitation among consumers in the largest automotive markets—China, Germany, and the United States. While many people consider purchasing EVs (36 to 80 percent of car buyers, depending on the market), few actually do (2 to 5 percent). This hesitation is also reflected in the OEMs' low levels of "EV sales readiness," documented in McKinsey's 2019 EV Mystery Shopping survey, which revealed the core challenges facing OEMs that sell EVs: their in-store presentation, the accessibility of test drives, and the EV knowledge and processes of sales associates. Sales staff must, for example, understand how to discuss total costs of ownership,

[1] IHS Markit (alternative propulsion forecast as of November 30, 2019).

Exhibit 1

Original equipment manufacturers face four main challenges in the electric-vehicle market.

Electric-vehicle (EV) go-to-market model

Regulatory environment

- Time to market is critical since OEMs will face severe regulatory penalties in many markets for failing to meet CO_2 emissions requirements from 2020 onward
- Gradual decline in government subsidies expected as technology advances

Customers

- Customers not yet requesting EVs; consideration is up 50% or more but purchase conversion still low
- Top concerns and purchase barriers involve batteries, driving range, and charging
- EV buyers have different preferences than internal combustion engine buyers, such as a preference for digital channels, app interaction, pay-as-you-go options, and personalization; they rely heavily on sales staff for advice

EV infrastructure

- Charging network rollout has been accelerated, but availability is still limited, especially for fast-charging stations
- Seamless and compelling charging experience is not yet widely available due to high market fragmentation
- Critical enablers still absent for scaling up EV aftersales and parts operations, such as battery recycling and re-usage capabilities

EV business case and profitability

- EV business case at risk, since consumers are not yet willing to pay extra cost of EV powertrain
- EVs have up to 60% lower aftersales revenues compared to vehicles with internal combustion engines

batteries, and charging. If OEMs do not address these issues proactively, the growing supply of EVs might outpace demand. OEMs would then be stuck between high penalty payments and rising incentive-spending levels.

The EV infrastructure

On the charging side, the EV infrastructure is insufficient. The network of charging stations, particularly fast-charging ones, is sparse. Battery quality, the time needed to charge, and limited access to chargers are the biggest concerns for potential EV buyers, accounting for 38 percent of all concerns raised.[2] The rollout of charging infrastructure is accelerating, but no integrated, seamless, and compelling solution is available, because the market is very fragmented. OEMs should take the lead in this area.

On the EV-parts side, challenges arise from long delivery times—especially for EV batteries—and the failure to prepare adequately for EV after-sales services.

The EV business case and profitability

EVs will become more crucial to the OEMs' overall success as they begin to represent a growing share of the portfolio. Profitability of the EV business case is at risk for many OEMs for several reasons, including the high investment required, initially low sales volumes, the high cost share of the battery, and lower aftersales revenues. This gap

[2] Thomas Gersdorf, Russell Hensley, Patrick Hertzke, Patrick Schaufuss, and Andreas Tschiesner, "The road ahead for e-mobility," January 2020, McKinsey.com.

could present challenges for both OEMs and their dealers. As we mentioned earlier, other issues—including falling government subsidies, increasing competition, and persistent customer concerns—also limit EV sales and put additional pressure on profitability. Without proactive countermeasures, it could fall enough to endanger the current business models of leading OEMs and dealers.

Seven innovations for GTM success

As we explained in our recent article on EV profitability, OEMs have previously attempted to tackle the businesses challenges primarily by making changes on the production and technology sides (for instance, improvements to battery sourcing, platform strategies, and alliances and ecosystems). Now, however, OEMs must also develop innovative GTM models to sell the required number of EVs and to find a sustainable business model. Our research and discussions with leading practitioners in the field have led us to believe that seven radical innovations in four areas—offerings, sales, after-sales services, and business models—will shape the OEMs' EV future (Exhibit 2).

1. Reinvent brand positioning

OEMs ought to create a compelling value proposition for their EVs, focusing on differentiating themes. The value proposition should align with the overall brand but also be specific to EVs. An OEM might, for instance, emphasize that it has a large charging network. Volkswagen, which emphasizes "E-mobility for all," provides a good example of effective positioning.

OEMs should also develop attractive new offerings: integrated EV-mobility bundles that include products and services, with a focus on the overall experience. In addition to the vehicle itself, for example, a successful bundle might include charging, on-demand features and services, revenues from data, financing options (such as battery leasing), mobility services, and after-sales packages (for instance, Care by Volvo). Combined, these elements could create a compelling offer that enhances the customer experience and may resolve concerns that could hinder the adoption of EVs.

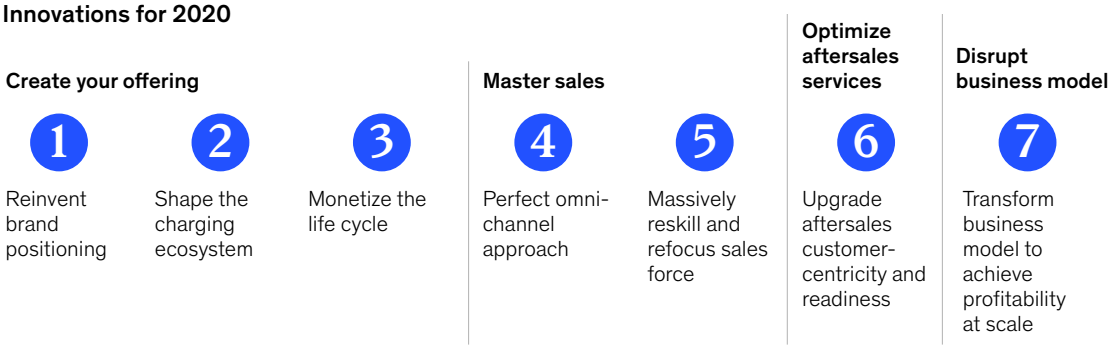
Communication will be the key: OEMs should use innovative and personalized approaches, such as digital campaigns, to reach and educate prospective EV customers. Focusing on areas and customer segments that are actively considering EVs will be critical to reach scale quickly and to create a network of EV advocates for each OEM brand.

2. Shape the charging ecosystem

Be early to provide a seamless charging experience. OEMs ought to develop and manage networks

Exhibit 2

Seven innovations will shape the electric-vehicle go-to-market model.



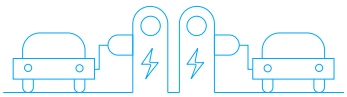
of leading ecosystem players to create end-to-end charging systems with single access points as quickly as possible—and at a reasonable cost to the consumer (Exhibit 3). To create such an infrastructure at scale, the OEMs should also integrate the different charging options (home, public, and dealer) into the existing system and app landscape, working closely with leading ecosystem partners.

First, OEMs should help enable home charging by bundling a cobranded wallbox with the EV, including a dealer margin to boost sales. In partnership with Centrica, for example, Ford offers home-charging installations and electrified-vehicle tariffs from British Gas. To address one of the most prevalent customer concerns, OEMs could also establish international partnerships to create a public charging solution with a sufficient network of both standard and fast chargers. These partnerships, including mobility service providers (MSPs) and governments, would enable retailers, offices, and residential buildings to install charging stations. A variety of payment models (for example, pay-as-you go or subscription) would have to be developed. Another possibility would be to accelerate the adoption of EVs, and to provide additional customer benefits that would increase loyalty, by using dealer networks to raise the number of charging points, especially in underdeveloped rural areas.

Exhibit 3

Original equipment manufacturers should provide convenient solutions for public and private charging.

Public charging infrastructure

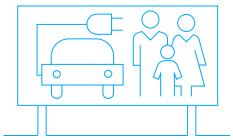


- Offer dense charging network directly or via mobility- or charging-service providers
- Engage in local partnerships with municipalities and infrastructure provider
- Help retailers, offices, and landlords install charging stations easily at low investment

43%

of battery-electric vehicles (BEVs) are charged on public charging stations

Proactively advertise new charging lifestyle

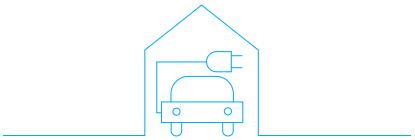


Team up with businesses or tourist stops on typical travel routes to make charging breaks appealing; in such locations, the 30-minute charging window could become an opportunity to enjoy the surroundings

40%

of public charging locations worldwide are in 25 cities

Provide easy plug-and-play solutions for charging at home



- Provide intuitive Wallbox installation service
- Educate electricians in charging-system installation and customer support
- Demonstrate charging systems live in-store and online
- Provide smart charging solutions through collaborations with utility companies
- Provide a seamless charging experience, regardless of location

64%

of BEV owners would like to or already participate in smart charging services

Finally, OEMs should secure access to the acquired data from charging and use them to generate income in the future and to develop smart charging solutions, such as those provided by Renault's Z.E. Smart Charge app. These solutions base charging recommendations on the available level of energy in the grid.

3. Generate income from the life cycle
Don't just sell cars; be there the whole way. In the OEMs' current EV GTM approach, they gain about €100 a year in profit (around 1 cent per kilometer driven) over a car's life cycle after selling a new vehicle.[3] (This profit does not include aftersales revenue.) Despite efforts to reduce the cost of producing EVs, this profit will increase only slightly in the next five to ten years. OEMs and dealers must therefore pursue other revenue opportunities throughout the product life cycle to achieve sustainable margins.

After the purchase, OEMs can, for example, offer on-demand services and features to consumers, as Tesla does through its AutoPilot. Such features might include performance- and battery-boosting software, advanced driver-assistance systems, and services like BMW ConnectedDrive, which includes remote services, concierge service, and on-street parking information, among other benefits. BMW, for example, offers ConnectedDrive in four packages that cost from €69 to €279 a year.[4] Given the attractive profit margins on those services, BMW is able to bolster the overall profitability of its EVs.

Either alone or with the support of third-party data aggregators, OEMs also have an opportunity to generate revenues from the data of customers and vehicles. These data could be used to address a number of use cases involving connected vehicles, to offer personalized services, or to provide third-party marketing. Our research indicates that revenues from data could generate approximately €50 a year per vehicle.

4. Massively reskill and refocus the sales force
Convert your dealers into true EV advocates. Only half of the sales reps in our mystery-shopping efforts at selected dealerships in China, Germany, and the United States conducted balanced discussions about the merits of EV and ICE vehicles when advising test customers who were generally open to both. From our perspective, there were several reasons for the problem: a lack of knowledge among salespeople about some of the potential benefits of EV, the human tendency to avoid criticism, and lower EV dealer margins and after-sales revenues. To change all this, OEMs must not only support their dealers as they build the required infrastructure and capabilities but also, at the same time, provide incentives that make EV sales more economically attractive over the long term. Without such efforts, dealers may wonder if it is worthwhile to sell EVs.

OEMs should monitor performance—both their own and that of third-party dealers—to ensure the consistent delivery of an optimal EV sales pitch. They should also invest in digitally savvy product "geniuses" to serve as trusted advisers for customers. To build the deep EV expertise that makes it possible to address all relevant customer concerns, OEMs should train the geniuses through online and in-person classes that explain integrated EV-mobility bundles.

OEMs should also give dealers incentives to increase the number of test drives, which would expose more customers to the new technology. OEMs could, for instance, encourage dealers to reach out to target groups, such as taxi companies and mobility providers, to get additional prospective customers behind the EV wheel. Finally, OEMs should ensure that all showrooms prominently display the entire EV portfolio (including wallbox and charging solutions) and that customers can explore them with digital tools.

5. Perfect the omnichannel approach
Make your online channel an information "El Dorado" for EV prospects, who want to know

[3] Assuming €1,000 margin on 100,000 km driven in a ten-year life cycle.
[4] Reference price in Germany as of May 2020.

about these vehicles and are upward of 50 percent more interested in purchasing cars online than traditional buyers are. OEMs should therefore invest significantly in their digital presence to provide easy access to information about important customer concerns; for example, OEMs could feature discussions about customers' key EV pain points on their websites. They could also reduce the complexity and uncertainty of a purchase by providing simple, care-free configuration and ownership options, such as subscription models that permit further personalization through on-demand features.

Ensuring seamless online–offline integration between digital touchpoints and dealers is important too. First, it helps dealers identify likely customers for EVs. Given the central role of online channels during the information phase, they will also have a growing importance in generating leads. Several OEMs have proved that innovative online–offline integration (for example, Polestar) and hyperlocal marketing can significantly increase walk-in rates. NIO has gone a step further and established a second floor in its flagship stores that is dedicated to its customers and their friends, with the goal of improving brand loyalty. The company also has an application that allows users to book services at one-click, share content with other NIO customers, and earn rewards by actively participating in the community.

Since more than 50 percent of prospective EV customers would be willing to purchase a car online, OEMs should also begin to pilot online sales approaches, as Tesla does, to provide a lean, cost-effective retail channel with direct access to customers.

6. Upgrade after-sales customer-centricity and readiness

Learn how to make your after-sales operations leap into the new age. EVs require less after-sales service than ICE vehicles do and have significantly different maintenance needs. They also require highly skilled technicians who understand battery and high-voltage technology. OEMs should therefore develop EV-specific training programs—in battery diagnostics, for example—to train the technicians in their dealer networks. It will also be important to ensure that EV-related parts and tools, such as battery-leak detectors, are easily available. Volkswagen, for instance, is planning to establish a new battery warehouse to pool its stock and provide fast deliveries to its dealers. While demand is still low, several dealerships could share these facilities.

OEMs and dealers should also create EV-specific service offerings and maintenance plans. EVs will have complex proprietary software. For after-sales service, many consumers will rely on the dealer networks affiliated with their cars, and that could partially compensate for lower profits in the overall EV after-sales and parts market (Exhibit 4). OEMs could also create EV-specific offerings to reassure customers by providing additional battery-related support (such as recharging services) via service partners. Such offerings might include long-distance replacement cars or distinctive warranty offers—for example, a battery-care package (similar to AppleCare), which Volkswagen already intends to offer.[5]

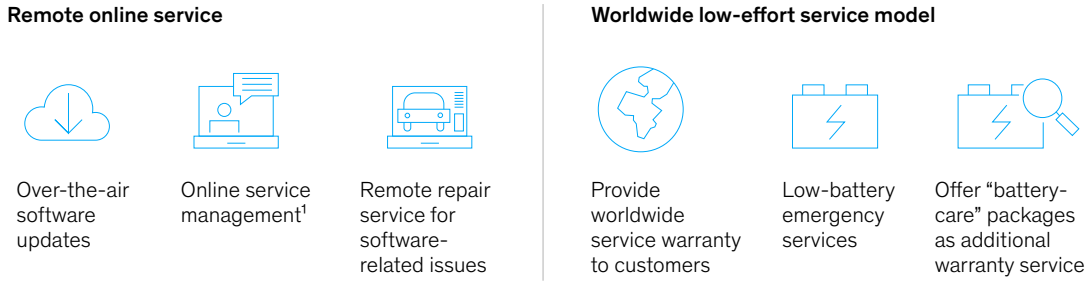
Finally, OEMs could provide state-of-the-art after-sales services (such as parts-exchange reminders and software updates) that are always available and can be sent, in part, remotely over the air. Such services could significantly improve the customer experience. Tesla, for example, already offers them.

Battery-reusage concepts are becoming more important as a result of increasing regulation in markets such as China and the European Union. OEMs and their ecosystem partners should start to develop their own ideas now, before a standard solution is established. Their efforts could lay the foundation for a possible future revenue stream and mitigate future risks from battery-handling and -recycling regulations.[6]

[5] Volkswagen plans to guarantee more than 70 percent battery capacity after eight years.
[6] For a deeper perspective on this topic, see Hauke Engel, Patrick Hertzke, and Giulia Siccardo, "Second-life EV batteries: The newest value pool in energy storage," April 2019, McKinsey.com.

Exhibit 4

Original equipment manufacturers can win customers over with superior services online and offline.



70%
of customers disagree with companies claiming to be customer-centric

71%
of electric-vehicle owners use it as their primary vehicle

40%
plan to change the car brand for better connectivity

[1]For example, upcoming checks, usage statistics, and other information are accessible online.

7. Transform the business model to achieve profitability at scale

Make the unprofitable profitable. For the foreseeable future, though, EVs will probably remain significantly less profitable than traditional cars as a result of higher production costs, lower after-sales revenues, continuing uncertainty about battery reusage and remarketing, and the significant investment required for the charging infrastructure. Additional revenue streams from on-demand services and features, and from sources such as data and charging, probably won't offset these cost pressures, so the current GTM model must further evolve. A new one will require greater online–offline integration, which will reduce costs across the physical retail network, since consumers will increasingly research and buy cars online. Such a model will also help OEMs shift toward more direct asset-light electric-mobility offerings.

In the short term, OEMs should focus on optimizing their existing dealer networks by easing standards, such as stock requirements. They should also continue to consolidate the number of dealers to achieve synergies through joint back-office operations and larger economies of scale. If necessary, OEMs could restructure their networks to rebalance profits across all stakeholders—for example, by reducing the number of outlets and moving to direct sales. An ICDP study expects that the number of outlets in dealer networks across Europe must fall substantially if they wish to remain viable.[7] Newer players, such as Byton, Polestar, and Tesla, already use that model by building their sales operations around a common digital backbone that seamlessly connects online sales.

In addition to supporting full-service dealers, OEMs should adopt leaner, more customer-centric retail formats, such as urban flagship stores and experience centers, depending on the needs of

[7] *ICDP European Car Distribution Handbook 2019.*

specific geographies. They can ensure quality of service by offering new after-sales concepts; for instance, Audi's digital service stations, providing automated check-in and check-out, are open 24 hours a day. To pool demand across dealerships, OEMs could also create large service centers in the outskirts of cities.

OEMs should partially transform their sales model from wholesale to retail by increasing their ability and efforts to generate high-quality leads. They should also partially shift to direct-to-consumer sales models (such as subscriptions) for selected geographies or offerings. A direct model implies reduced margins for dealers and more direct access to customers for OEMs.

Before scaling up any changes, OEMs should start pilots to explore and assess a variety of business models. Several OEMs (for example, Mercedes in Sweden and Toyota in New Zealand) have already conducted such experiments. The knowledge gained from them will help the entire industry to mitigate implementation problems, such as insufficient pricing, failed stock management, and unclear marketing responsibilities.

New mobility concepts can also be part of that business-model innovation. OEMs, for example, may gain new revenue streams by creating regional shared-EV pools for major European cities or EV fleets for urban taxi providers. If such mobility services use a subscription-based pricing model, they can help hedge against falling EV prices. The same holds true for other offerings (such as battery-leasing services) related to new mobility concepts.

The time has come to revise the GTM model for EVs. OEMs can start by taking the following steps:

First, they should use EVs as an accelerator to modernize the GTM. By piloting and quickly scaling up the required short-term measures for online channels, the offline experience, after-sales services, network restructuring, and the like, OEMs can ensure a high level of readiness when new EVs are ready to launch.

Second, OEMs should prepare for novel sources of revenue. They ought to launch and support their markets while dealers tap into new revenue streams, such as charging, bundles for EV mobility, on-demand features, and data from vehicles.

Finally, to stay ahead of the curve, OEMs should be ready to leap by exploring new business models, including alternative sales models, mobility solutions, and battery-reusage concepts.

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Subscribed to future auto finance yet?

Auto financing's future will be dynamic, disruptive, and different. Here's our perspective on the European market.

November 2019

This article was written collaboratively by members of McKinsey's Automotive and Assembly and Financial Services practices. The authors include Sebastian Kempf, Benjamin Koeck, Tobias Schneiderbauer, Ursula Weigl, and Romain Zilahi.

The auto-financing market has been evolving in response to macroeconomic developments, changing consumer behavior, and new regulations.

Now COVID-19 is stimulating even greater changes in these areas, and the abrupt economic shock has produced a steep and unexpected decline in sales of new and used cars. The pandemic has also triggered major, unprecedented shifts in mobility patterns, including use of ride-sharing services, public transportation, and private cars. All of these changes will ripple back to affect automotive financing.

To help European auto-financing players navigate this changing landscape, we have comprehensively researched the issues confronting their industry and surveyed more than 30 auto-finance executives within Europe about current trends and dynamics. (For more information, see the sidebar, "The nuts and bolts of our survey.") This article consolidates our findings on potential growth opportunities, future strategies, and organizational challenges in the European market.

The current situation and future prospects for the auto-financing market

The auto-leasing and auto-loan sectors are billion-euro industries in Europe, but slowing auto sales and changing mobility patterns have taken a toll. COVID-19 will likely to continue to depress automotive revenues through 2021, but the impact will vary by segment. Auto leasing is expected to recover sometime in the second half of the year, but the auto-loan market may not recover until around 2023 to 2024, partly reflecting its limited growth trajectory over the past few years. Depending on the scenario, the auto market will have a steep to very steep dip in 2020 followed by either a slow or somewhat faster recovery.

Despite the current challenges, many new players are entering the auto-financing market, including fintechs, independent leasing companies with digital channels, and automotive OEMs. The latter have captive-financing arms that are partnering with or even building their own fintechs.

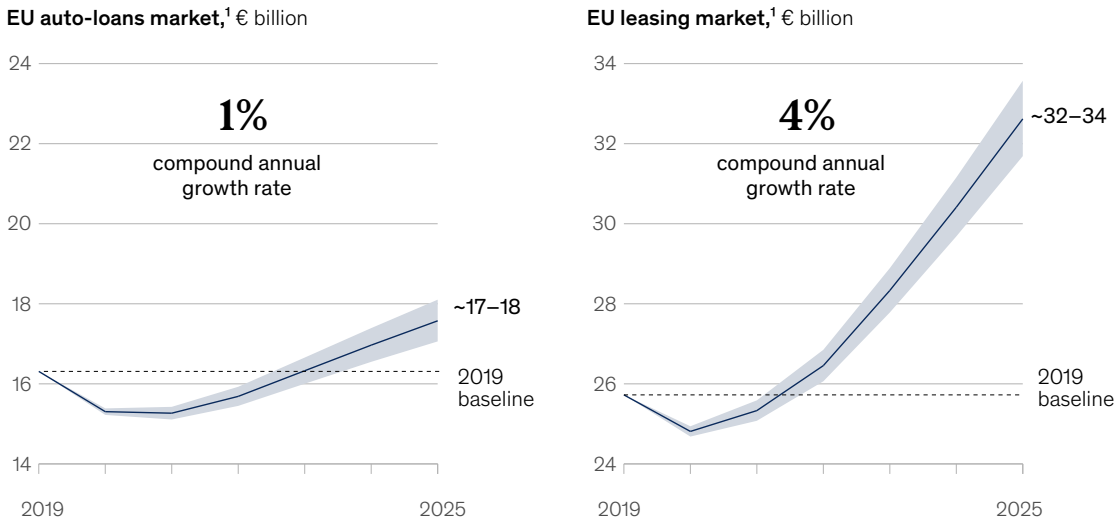
The emerging subscription business, one of the industry's fastest-growing segments, is also altering market dynamics. Industry players that want to stimulate long-term growth are increasingly exploring this model, because consumer interest is so high. The appeal of subscriptions is driving higher growth rates in the leasing market.

Our research suggests that both the European leasing and auto-loans segments will grow through 2025 (Exhibit 1). In the McKinsey European Auto Finance Survey 2020, respondents also anticipated many other changes ahead, including growth of the subscription market. These trends are discussed in more detail later in this article and summarized in the sidebar titled, "Facts about leasing and auto loans in Europe."

Exhibit 1

Leasing will likely recover more quickly than auto loans.

Auto-financing retail and corporate revenues before risk cost (interest + provision result)



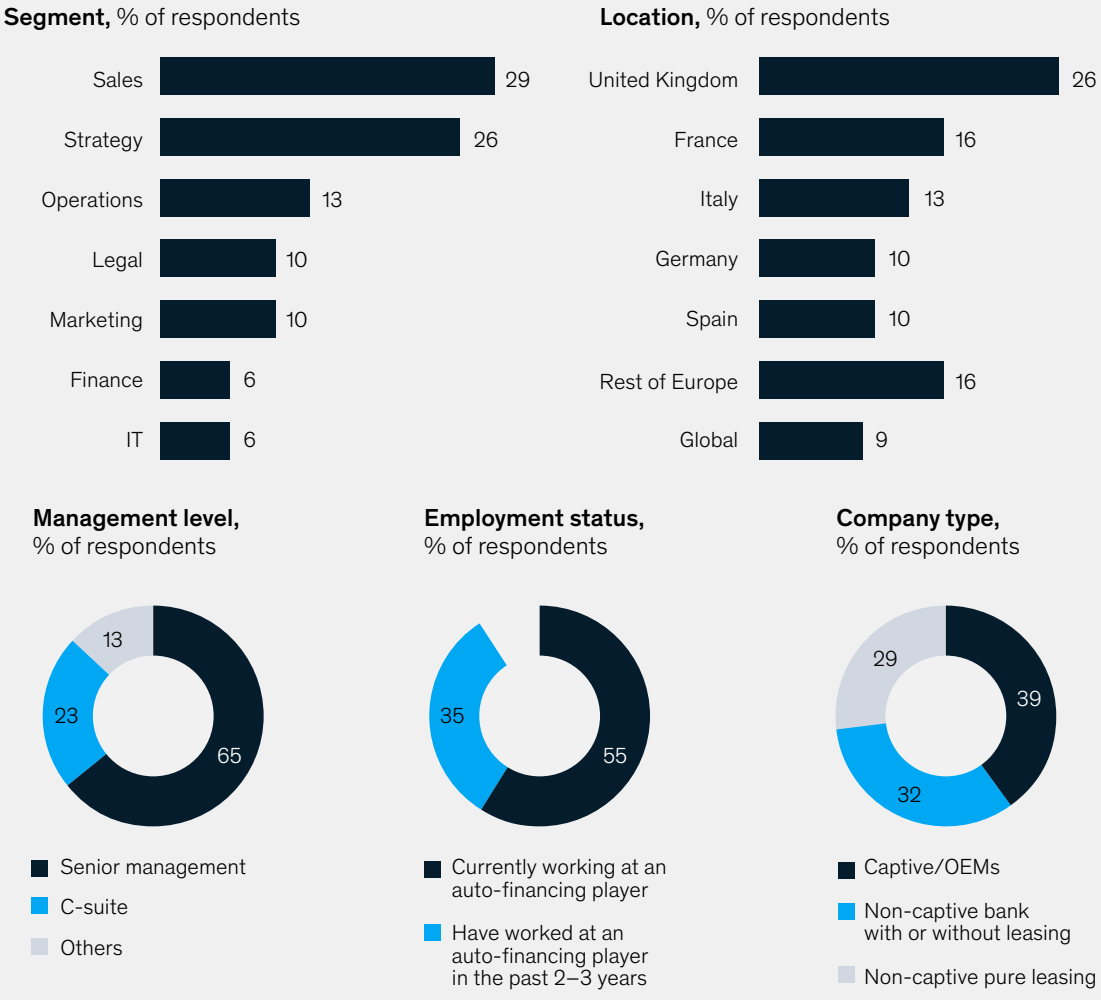
[1]Growth rates with sensitives of +/– 0.5%.
Source: McKinsey European Auto Finance Survey 2020

The nuts and bolts of the McKinsey European Auto Finance Survey 2020

To research Europe's auto-financing industry, we interviewed more than 30 industry experts from leading leasing companies in the region. The respondents included professionals in sales, strategy, operations, and marketing (Exhibit). Most (39 percent) worked for the captive-financing arms of automakers, 32 percent for non-captive banks, and 29 percent for non-captive, pure leasing companies. The respondents were from major markets across Europe, including the United Kingdom.

Exhibit

Our survey involved interviewing more than 30 industry experts from leading European leasing companies.



Source: McKinsey European Auto Finance Survey 2020

Changes within the consumer base

In past financial contractions, consumers postponed discretionary purchases and increased their savings as they braced for harder times ahead. These trends are already apparent with COVID-19, as seen with the steep decline in private-vehicle sales.

According to recent McKinsey research, discretionary consumer spending could decline by 40 to 50 percent, translating to a roughly 10 percent reduction in GDP and numerous second- and third-order effects in 2020. The continued consumer wariness will significantly decrease light vehicle sales for 2020 as a whole, and it could also prompt buyers to purchase smaller vehicles than originally planned. "Nearly new" used cars could see increased demand, since consumers may be willing to accept a car with some mileage if the price is competitive.

We believe that private-vehicle sales will soon begin to improve, although they will remain slightly below pre-crisis levels over the medium term. In the first half of 2021, consumers in most regions will continue to delay auto purchases, but China could see sales begin moving toward their pre-crisis levels. We expect a recovery in second-half 2021, driven by GDP growth resulting from government subsidies and lower interest rates. There is still much uncertainty, however, since much depends on how the pandemic will evolve and how rapidly the economy will stabilize again. We expect that light vehicle sales losses across the EU will total 5 to 10 percent in 2021 compared to pre-COVID-19.

A greater shift to digital and direct B2C channels

In addition to depressing auto sales, COVID-19 is shifting consumer behaviors. Already, the pandemic has accelerated the growth of digital and online channels for business-to-consumer (B2C) purchases. In response to these trends, OEMs have begun to "virtualize" their dealerships and operate remotely. Sometimes, they offer fully contactless test drives and servicing. With sales, some representatives now completely conduct business online. Non-digital marketing activities also are decreasing as consumers migrate to online channels.

Many new fintechs in the EU market offer products through online and mobile channels, and this could give them an edge against more traditional players. McKinsey's automotive and mobility consumer insights survey shows that at least a third of consumers across European markets already prefer digital sales channels. In-person interactions at auto dealerships, which were already in decline, could fall further as economies move into the recovery phase.

Based on their experience with retail purchases, customers now expect a seamless online experience, including hassle-free pricing and data sharing for reciprocal benefits. Other products, such as rental and shared mobility services, could become part of an integrated multimodal bundle resulting in a seamless mobility solution for all circumstances.

Increased customer interest in auto subscriptions and leasing

The consumer shift toward flexibility is fueling the expansion of the subscription market, which partly explains why leasing is seeing higher growth than auto loans. Companies are primarily targeting the B2C segment with subscription offers, since they know many consumers want the greater flexibility that comes with shorter contracts and a pay-as-you-go model. Consumers may also appreciate that some subscriptions include services such as vehicle maintenance and insurance.

Driving the next normal in auto financing

The auto-financing industry in Europe will change as major trends fundamentally alter how people think about and purchase mobility. To thrive in the new landscape, the following actions are critical (Exhibit 2):

1. Defend—establish post-COVID-19 resilience
2. Deliver—strengthen the core business
3. Disrupt—reinvent future offerings to meet customer needs and drive a stellar customer experience

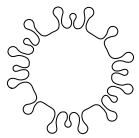
Exhibit 2

To thrive in the new landscape, auto-financing companies must focus on three measures.

Suggested actions to be taken

Defend

Establish post-COVID-19 resilience



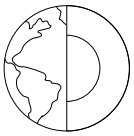
1 Manage residual value and remarketing of leasing returns

2 Manage collections effectively and efficiently

3 Optimize funding and capital efficiency

Deliver

Solidify the core business



4 Digitize core processes for cost excellence and quality

5 Upgrade IT/tech capabilities for faster time-to-market

6 Establish a high-performance agile organization with new skills/talent

Disrupt

Reinvent future offering

7 Address and scale used-car (leasing) offerings

8 Activate and scale B2C channel

9 Develop products in line with customer needs, such as subscriptions

Defend—inoculate against COVID-19 to establish strong resilience

The COVID-19 crisis has exposed vulnerabilities in business models across industries. To build resilience, auto-financing and leasing companies should focus on three activities.

Managing residual values and remarketing. Our executive survey suggests that many auto-financing players do not yet have optimal risk-management strategies for preserving the residual value of leased vehicles. To improve, they should embrace active inventory planning and increase their data-driven decisions. Healthy residuals, plus effective remarketing practices for off-lease cars, will give companies a powerful one-two combination on this uncertain new playing field. Companies must also improve risk-adjusted pricing to avoid unexpected losses and ensure the efficient turnover of vehicles that are returned after leasing contracts expire. This step will ultimately result in lower inventories.

Improving collections effectiveness and efficiency. Financial resilience requires strong cash-management skills, especially when it comes to reducing the volatility of cash flows. Our executive survey suggests that many auto-financing players still need to improve these capabilities. More than half the respondents stated that their collections-management capabilities were mediocre, with an average efficiency score of 2.9 on a scale of 1 to 5, suggesting that this area needs particular attention. Improving the turnover within accounts receivable will naturally translate into better collections, allowing companies to avoid a crunch at a time when cash is king.

Optimizing funding and capital efficiency. Pure leasing companies that lack banking licenses have little access to deposits to refinance. In consequence, they often tap into refinancing solutions that go beyond current funding sources to ensure future portfolio growth. Many of these non-traditional solutions are already common in certain regions. For instance, US leasing companies frequently self-fund through the securitization of residual values while simultaneously using leasing rates as the basis for structured asset-backed security (ABS) transactions. In Europe, especially

Germany, players remain conservative about refinancing strategies. Our survey showed that the main funding tools in Europe involve lease ABS transactions, while few companies use residual-value-backed ABS transactions (Exhibit 3).

Deliver—add implementation muscle to strengthen the core business

To build post-crisis resilience and ensure long-term success, companies must strengthen their core business. Again, three activities are critical.

Digitizing core processes to achieve cost excellence and improve quality.

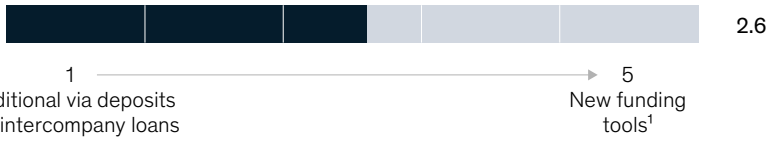
Companies need a strong technological backbone to support product development and go-to-market strategies. To reduce inefficiency and cost pressure, they should replace clunky manual processes with automation, digitization, and end-to-end solutions (for instance, tools and processes that help them interface with car-dealer systems). Fortunately, most auto-financing players already recognize the importance of building a solid foundation. In our survey, respondents stated that digitizing core processes was their top priority for the next one-to-two years. Building a strong technological backbone was ranked third (Exhibit 4).

When automating and optimizing processes, companies can take a multi-lever approach—digitization, robotic-process automation, simplification, business-process optimization—across operation centers or build real-time decision engines that deliver answers faster. Among other benefits, digitization and automation will help companies expand their online offerings and B2C channels, providing the high-quality customer experience that consumers increasingly expect.

Exhibit 3

Auto-financing companies should consider nontraditional refinancing.

Innovation in refinancing strategies, average respondent rating (on a scale of 1–5, with 1 = low innovation and 5 = high innovation)

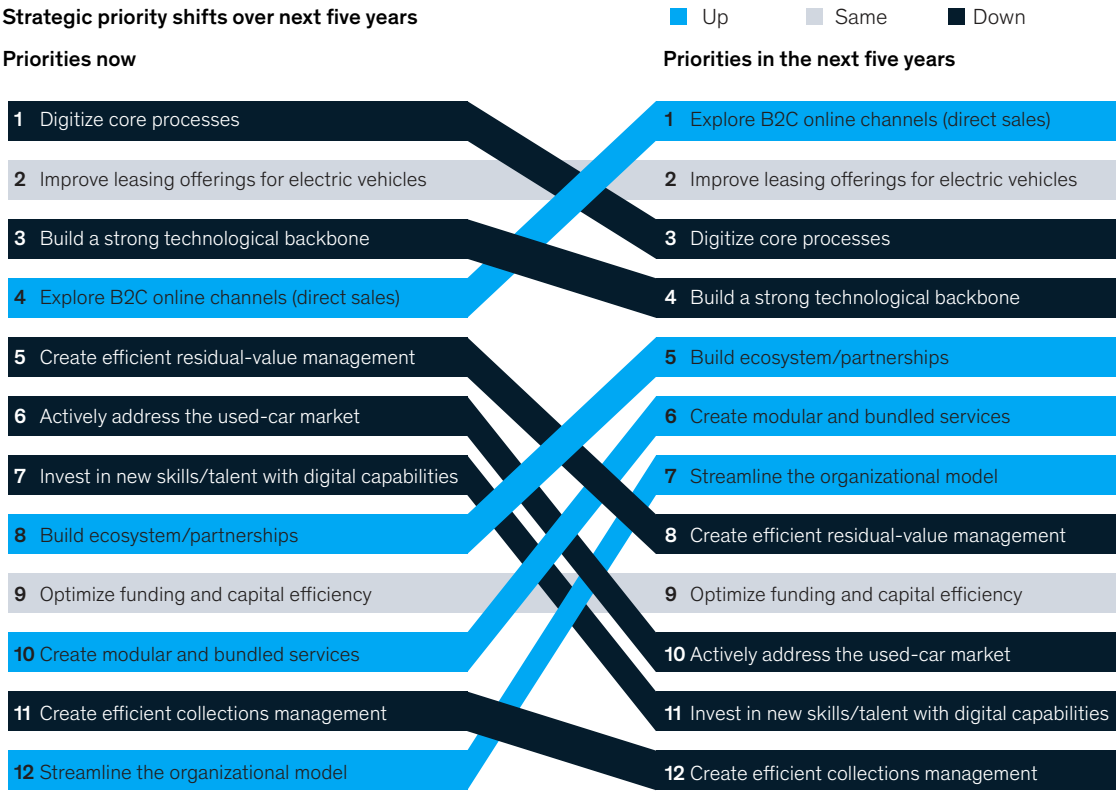


Use of current funding tools , % of respondents

[1]New funding tools include residual-value-backed asset-backed-security transactions.
Source: McKinsey European Auto Finance Survey 2020

Exhibit 4

The strategic priorities of auto-financing executives are shifting.



Source: McKinsey European Auto Finance Survey 2020

Updating IT and tech capabilities to decrease time to market.
Successful auto-financing and leasing companies depend on technology. IT is the largest cost driver in transformation projects, but it enables future growth, and supports the viability of the entire business model. Our executive survey revealed that auto-financing players believe that a gap exists between the current and expected future state for their IT and technology capabilities.

Companies that want to upgrade their tech capabilities must undertake a profound transformation. Rather than viewing themselves as traditional financial-services players, they will become tech companies that offer products in the financial-services space. This new image will ensure that auto-financing and leasing companies give IT the attention it deserves. Organizations focused on the creation of a lean technology backbone will automatically question whether they should retain legacy systems and complex architectures and processes as they transform.

Establishing a high-performing agile organization with new skills and talents.
To create innovative products and stay ahead of the game in an increasingly competitive market, organizations must adapt. Our executive survey reveals many auto-financing players still need to become more agile and adopt new ways of working. By implementing an agile organization with low hierarchy and strong cross-functional teams, companies can co-create products with customers in quick, iterative steps. This strategy allows them to tailor products based on customer behaviors and needs while simultaneously delivering new digital solutions. The focus on aligning IT with business objectives will also help organizations build their B2C business further and achieve their priority goals for improving their online presence.

Our survey respondents said the two top skills needed for sustainable growth were digital knowledge/expertise and IT expertise (Exhibit 5). We believe that European captive-financing players particularly need data scientists. Once companies adopt new ways of working, they may attract more top talent with the digital and IT capabilities required to fuel product innovation.

If companies streamline their organizational models by reducing reporting layers and adjusting spans of control, they can reduce costs while driving agility. Likewise, a continued focus on optimizing processes and reducing complexity will allow them to simplify the product portfolio. Together, these combined improvements will drive additional gains. For instance, a company might assign agile squads to cover certain areas of the simplified product portfolio to identify even more opportunities for cost and complexity reductions.

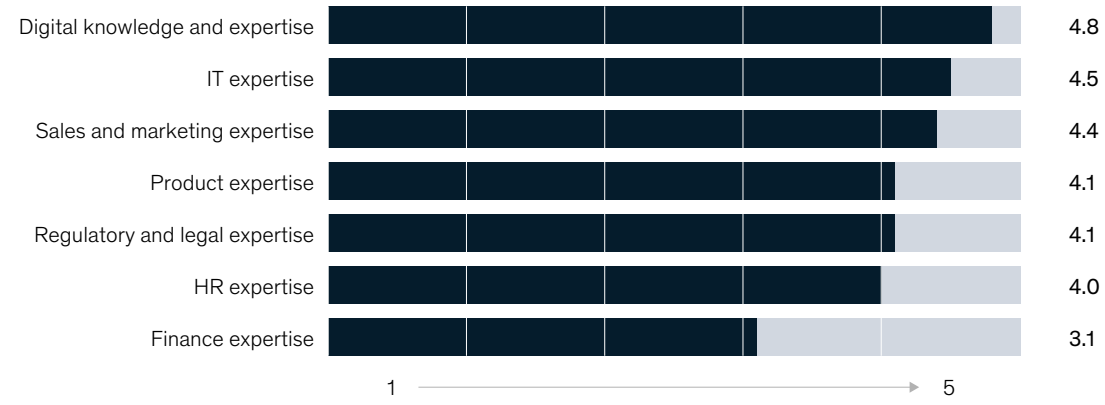
Disrupt—change the game by reinventing future offerings

To achieve long-term success, auto-financing players must identify growth pockets, introduce disruptions, and ideally boost coverage in these areas. The following activities will help in all respects.

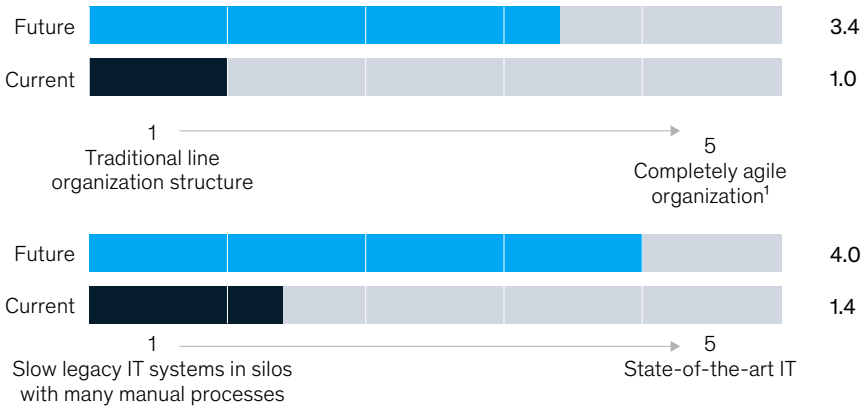
Exhibit 5

Digital and IT expertise are in high demand, but executives recognize that they need better capabilities.

Capability importance for strong future growth, average respondent rating (on a scale of 1–5, with 1 = not relevant and 5 = extremely relevant)



Current capabilities compared to essential future capabilities, average respondent rating (on a scale of 1–5)



[1]Organization with cross-functional teams and new ways of working.
Source: McKinsey European Auto Finance Survey 2020

Facts about leasing and auto loans in Europe

Here are some of the main data points we uncovered about the European market, both from research and our survey.

The EU auto-loan market:

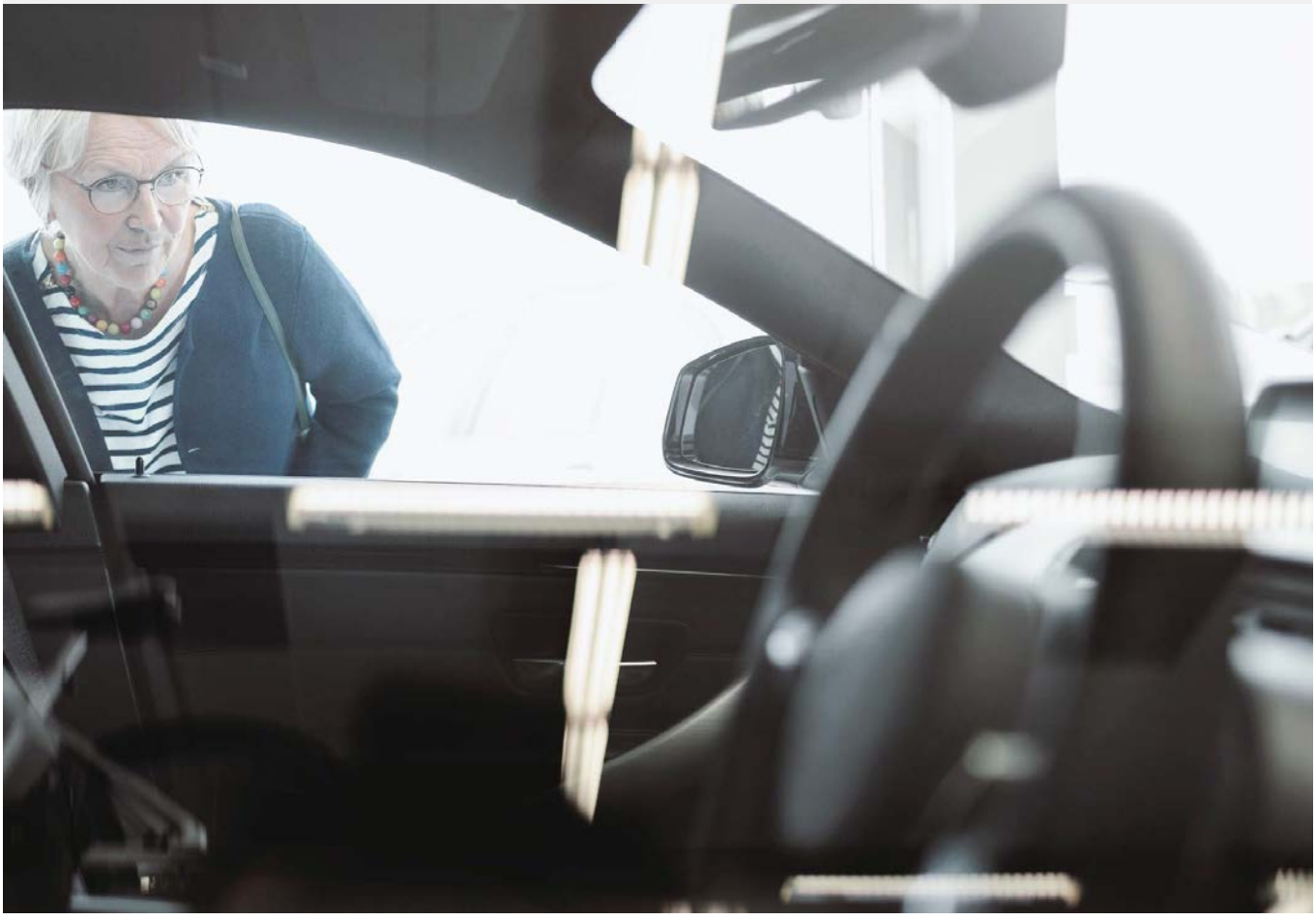
- Was worth about €17 billion in 2019
- Will be worth about €17 billion to €19 billion by 2025
- Is expected to have a compound annual growth rate (CAGR) of about 1 percent from 2019 through 2025

The EU leasing market:

- Was worth about €25 billion in 2019
- Will be worth between €31 billion and €34 billion by 2025
- Is expected to have a CAGR of about 4 percent from 2019 through 2025

Key findings from the McKinsey European Auto Financing Survey 2020 include the following:

- Respondents expect the subscription market to increase to reach a share of 20 percent of the total retail-financing market by 2025; about 25 percent of respondents even expected growth to a 25 to 35 percent share
- Respondents expect the direct B2C online channel to reach a 20 to 25 percent share of total sales
- About 95 percent of respondents rated offerings for electric vehicles as important or extremely important when ranking their strategic and financial priorities for products
- About 90 percent of respondents rated modular offerings as important or extremely important in their strategic and financial priorities for products



Actively addressing the used car market. Leasing companies have recently been placing more emphasis on the used-car market. They could accelerate business even further by devoting more attention to the B2C segment, which is generating more customer interest in Europe. Worldwide, several fintechs—Carvana and Vroom in the United States and HeyCar, the VW subsidiary—are already targeting the B2C used-car segment. Some players, including AutoBorse (Santander), HeyCar, JuhuAuto (BDK), Spoticar (Groupe PSA), and VivaCar (CGI) are focusing on controlling the customer front end by building their own online B2C marketplaces. Other companies that enter the B2C segment should also make this a priority. These marketplaces could even become remarketing channels, further contributing to vehicle disposal efficiency.

In another shift, companies should invest in adapting their residual-value models for used-auto leasing. This step will help increase financial stability while reducing unexpected losses.

Activating and scaling the B2C online channel. Organizations should activate and scale their B2C channels to reach new customers, since online and digital options are rapidly becoming more popular. Among other benefits, online channels will give customers the flexibility they now expect while facilitating the shift toward direct-to-consumer interactions.

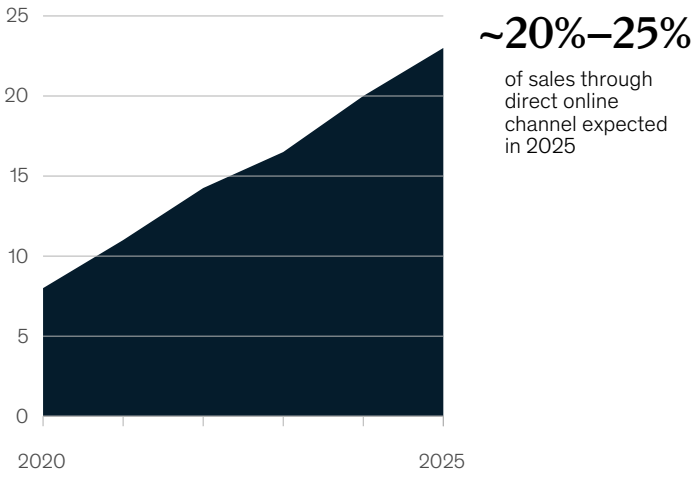
Auto-financing players are focused on digitizing core processes as quickly as possible, since this is necessary to expand B2C channels. In our survey, OEMs and captive players were especially set on this goal. Companies should also digitize their distribution channels and services by building integrated platforms that offer extras, such as remarketing, insurance, or repair services.

The industry is already experiencing high online and mobile traffic volumes, and the COVID-19 pandemic will likely accelerate growth in these channels. Our survey showed that auto-financing executives expect about 20 to 25 percent of B2C sales for auto leasing and loans to go through online channels by 2025 (Exhibit 6). Respondents from captive-financing arms were most conservative, with estimates of about 20 percent, while pure leasing players expected a share of around 30 percent.

Exhibit 6

Auto-financing executives expect online business-to-consumer sales for auto loans and leasing to reach a market share of around 20 to 25 percent by 2025.

Expected share of online B2C sales for auto loans and leasing until 2025, % estimated by respondents



Source: McKinsey European Auto Finance Survey 2020

Like independent leading players and fintech companies that target their customers via online and mobile platforms, such as LeasePlan with CarNext, OEMs can capture growth opportunities by scaling their online channels. This step will likely require new partnerships and alliances, especially with giant non-automotive e-commerce players. By increasing their online channels, OEMs will be able to attain other strategic goals, such as the development of mobility-as-a-platform offerings that combine different modes of transportation on a single platform. These new business models will likely require heavy investment in platforms and car fleets, as well as new partnerships with private-equity funds, banks or captive-financing arms that can provide funds.

Developing new financial products.
As customer preferences shift from owning to using, flexibility is becoming more important. In other words, consumers know exactly what product combination they need, as well as the exact timeframe when they will use it. The growing preference for flexibility will create opportunities for incumbents to venture into new business areas, but it will also give challengers a chance to gain market share by introducing new offerings and business models.

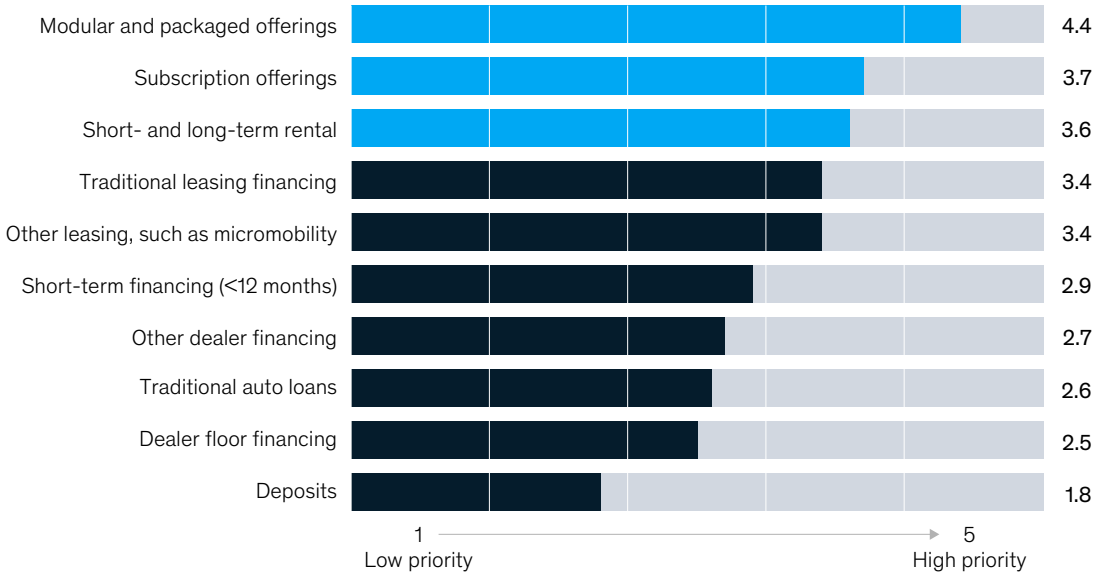
To succeed in the new landscape, companies should reevaluate all current products against key performance indicators (KPIs) to determine if they should be eliminated or simplified. They should then supplement their existing offerings with innovative products that will help them compete with newcomers. Modular/packaged offerings, subscription offerings, and rentals are all priorities (Exhibit 7).

Satisfying demand for modular or full-service offerings.
As noted earlier, private and corporate customers increasingly want flexibility. This preference extends to product bundles, since many customers now want to choose a specific combination of products and specify the timeline for their use. New forms of shared mobility are gaining market share since they provide flexible alternatives to private-vehicle ownership. Eventually, they will reshape the private-vehicle market.

Exhibit 7

Modular and packaged offerings are the top product priority for auto-financing players.

Strategic and financial priorities of product offerings, average respondent rating (on a scale of 1–5)



Source: McKinsey European Auto Finance Survey 2020

Senior executives in the auto-financing sector could create several options to satisfy customer demand for modular and packaged offerings. For instance, companies could offer a set of modular services that complement the product portfolio, such as maintenance and repair services. Customers would have the freedom to choose among add-on modules, such as a subscription for tires, with leases and other products. They could also select or drop modules over time.

As a first step, auto-financing players must develop a technology landscape, including the right IT systems, partnerships, and distribution channels, to deliver these modular innovations, if they have not already done so. They should also redesign contracts to allow customers to terminate individual elements. Other products, such as rented and shared mobility, could become part of an integrated multi-modal bundle—for instance, a contract that offers a leased car and an option for a ride-sharing service—to allow for a seamless mobility experience, regardless of location.

Increasing the focus on subscriptions.
As more consumers seek flexibility, demand is rising for subscription offerings, where customers pay a fixed, usually monthly, fee for a vehicle. While these are still niche products, auto-financing players should launch a comprehensive subscription offering that allows customers to add or subtract modules as they desire. Our experience shows that companies can often reorient their product landscapes to focus on such products within 24 to 48 months.

Subscription-based offerings show strong promise. In our survey, senior executives expected that they will represent about 20 percent of the total market by 2025. While this estimate may seem ambitious, we do believe there will be exponential growth in this area. High demand exists for fully flexible products, such as leasing models with non-binding durations, but only a few such offerings are available.

Automotive OEMs, rental companies, and new market players already offer some subscription-based products but availability varies by region. OEMs mostly offer products, such as Audi select, Access by BMW, and Free2Move by Groupe PSA, in the United States. In Europe, fintechs dominate the market, with offerings such as Cluno and ViveLaCar, and OEMs still have limited presence. Volvo does have an offering called Care by Volvo in Europe, however, and other OEMs may find opportunities there.

Most subscription offerings include added services as part of an all-inclusive or modular add-on package. These might involve maintenance, insurance, or concierge services. Some subscriptions also allow vehicle swaps at the end of each period, or even during a running contract.

Subscription-based offerings show strong promise. In our survey, senior executives expected that they will represent about 20 percent of the total market by 2025.

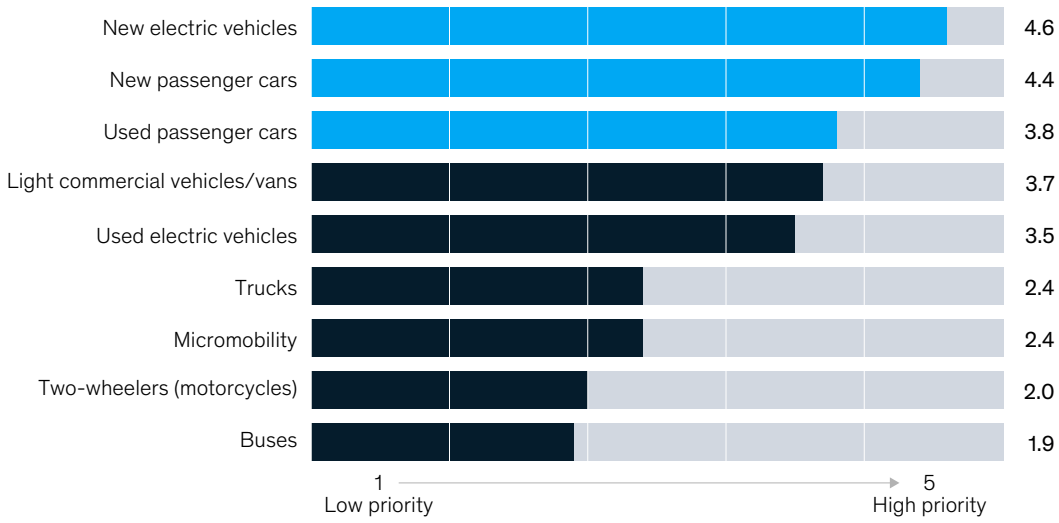
Driving toward more sustainable mobility with EVs. When asked about product priorities, executives in our survey ranked offerings for new EVs first (Exhibit 8). Given the growing popularity of these vehicles, auto-financing companies must develop advanced residual value models internally or jointly with partners to manage battery risk. Leasing products and services can give customers a hedge against the prevailing uncertainty about battery lifetimes and quality. Auto-financing players should also improve their prediction accuracy and residual-value models for EVs so they can offer competitive leasing rates. Players may need to review their appetite for risk regularly and understand the implications of adding risk to the balance sheet. (For information on the regulatory factors that might encourage the growth of EVs, see the sidebar titled, "The potential impact of regulations on the growth of electric vehicles.")

Companies that provide mobility-as-a-service offerings must also develop innovative services, most of which will likely involve connectivity packages and mobility budgets that allow for integrated multi-modal bundles. There will also be a greater need for packaged offerings that allow customers to lease EV-charging infrastructure, and some companies are already moving in this direction. For instance, LeasePlan and ALD partnered with a fintech to provide EV charging infrastructure in their offering. Additionally, companies should consider creating a new product category related to the modular financing of EV batteries—both their purchase and potential servicing—or work with a partner to develop one.

Exhibit 8

Auto-financing players state that offerings for electric vehicles are their top priority.

Strategic and financial priorities of product segment (offerings per vehicle type), respondent rating (on a scale of 1–5)



Source: McKinsey European Auto Finance Survey 2020

The potential impact of regulations on the growth of electric vehicles

Regulatory changes could also affect the types of vehicles that consumers buy or lease, as well as their mobility patterns. For instance, electric vehicles (EVs) may see increased demand within the leasing segment. While consumer interest is a factor, EVs will also benefit from regulatory tailwinds in Europe, where strict CO2 targets will most likely remain unchanged. In fact, Germany and France have already agreed to additional financial incentives to stimulate EV demand. Current indicators suggest that EV demand is stable in Europe and may even expand throughout the crisis. Volume and premium OEMs are likely to stick to their EV start-of-production dates to meet CO2 targets, since regulations established prior to the COVID-19 crisis will impose penalties for falling short of these goals in 2020 and 2021. Such penalties could run as high as several billion euros according to our internal estimates.

Many cities are also likely to implement more policies that suppress private-vehicle ownership and incentivize more sustainable modes, such as shared mobility. These policies will first roll out in large cities and reach other areas later in the decade. The pop-up bike lanes in several large European cities give some clues about what might be in store in other locations. City center bans and congestion charges to disincentivize private-vehicle ownership might also emerge. In Paris for instance, city officials have reduced parking spaces and the number of car lanes but increased support for EV car-sharing solutions. As with the growth of EVs, such changes will ultimately affect the auto-financing market.

Getting started

In the light of recent developments, including the repercussions of COVID-19, Europe's auto-financing players need to reposition themselves for success, and the time to act is now. That means resiliently defending their chosen value, delivering needed changes to safeguard the core business, and disrupting markets to capture new sources of revenue. We believe those who fail to capitalize on current trends now will be left behind.

Defend
Continue to build COVID-19 resilience for the short and medium term by optimizing collections, improving residual value management, and rethinking refinancing strategies. Companies should shift to more innovative funding tools, such as residual value-backed ABS. For instance, they could optimize finances and analytics by building a calculation engine for residual value, or by optimizing a sustainable refinancing strategy to encourage growth. Companies should also review best practices that other players have recently implemented to derive important lessons.

Deliver
Build a solid foundation to launch the company forward by strengthening the core business. This will involve digitizing core processes, creating a sturdy technological backbone, and upgrading internal capabilities (for example, through process optimizations, IT diagnostics, and agile organization transformations). Now is the time to double down on digitization and enhance digital capabilities to build a foundation for growth.

Disrupt
Develop product offerings that are more flexible, such as modular subscriptions, and activate B2C channels to reach customers more efficiently and effectively.

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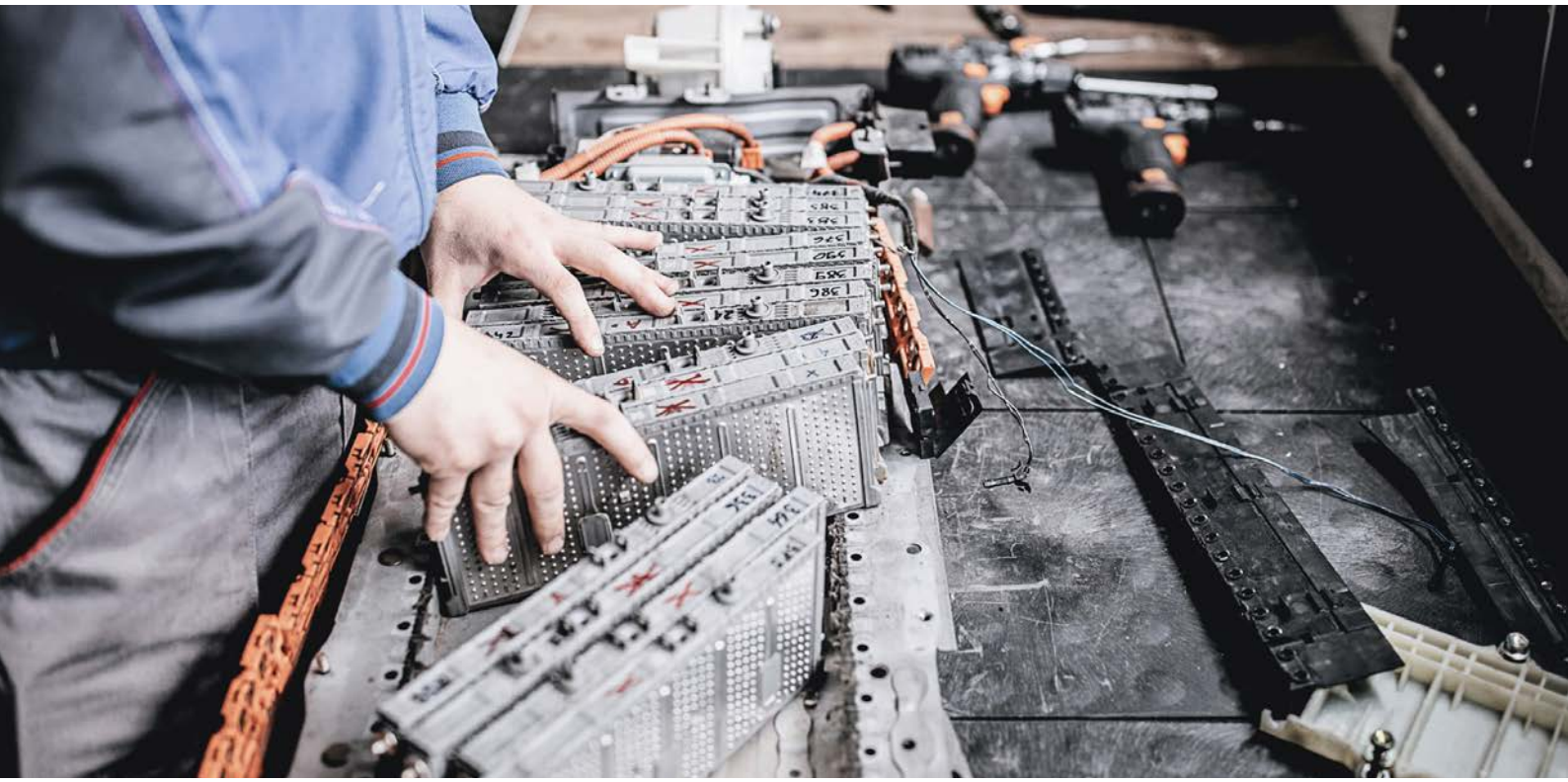
Improving battery-electric-vehicle profitability through reduced structural costs

As sales of battery electric vehicles increase, OEMs need to focus on R&D excellence, flexible manufacturing, and value-chain integration to improve profitability.

September 2020

This article was collaboratively written by colleagues from the McKinsey Center for Future Mobility. The authors include Andreas Breiter, Paul Hackert, Will Han, Russell Hensley, and Dennis Schwedhelm.



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Electric mobility was just about to reach a tipping point in core markets when COVID-19 hit, disrupting automotive sales worldwide. With battery electric vehicles (BEVs), as with other categories, the impact varies widely by region, depending on government intervention, infection rate, and other factors. In regions where governments are trying to encourage electric-vehicle (EV) sales growth through various policies and regulations, the BEV market is expected to grow. For instance, China could see higher sales because the government recently extended purchase subsidies through 2022, and Europe is providing OEMs with EV-production incentives tied to its targeted fleet average of 95 grams of CO_2 per kilometer. In the United States, where the government has relaxed emission standards and imposes relatively low gas taxes, BEV sales are expected to decline more steeply and take longer to recover.

Even in countries where BEV sales are picking up, many automotive executives are concerned about profitability. Some EV OEMs have already begun investigating changes to their go-to-market models that may increase sales and reduce costs quickly. Over the midterm, however, they will need to apply additional measures to be profitable, and our recent research shows that three levers will be particularly important in this respect:

— *R&D excellence.* Four research and development (R&D) levers—platform modularity, virtual prototyping, agile processes, and complexity management—can increase R&D efficiency by 15 to 20 percent.

— *Flexible manufacturing.* Staggering spending can enable companies to defer about 25 percent of large capital expenditures (capex) while providing near-term flexibility as volume slowly ramps up.

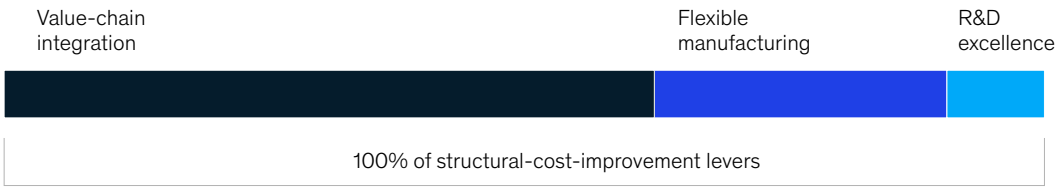
— *Value-chain integration.* Buying battery cells, e-motors, and inverters while retaining battery-pack integration and assembly in-house can reduce total vehicle cost by roughly 2 to 3 percent compared with an outsourcing strategy.

These three levers, combined, can produce major reductions in total vehicle cost over the midterm. Exhibit 1 shows the percent of total vehicle cost that each lever can address; these percentages vary by vehicle.

Exhibit 1

Three improvement levers can significantly reduce total costs for battery electric vehicles.

Addressable costs, % of total costs



Note: Typical example; exact figures vary by vehicle.

The current BEV market

Stronger regulations and growing consumer interest have recently accelerated the market shift toward EVs. For BEVs, a continuous decline in battery prices has contributed to growth and helped market penetration grow more than 40 percent annually from 2016 through 2019.

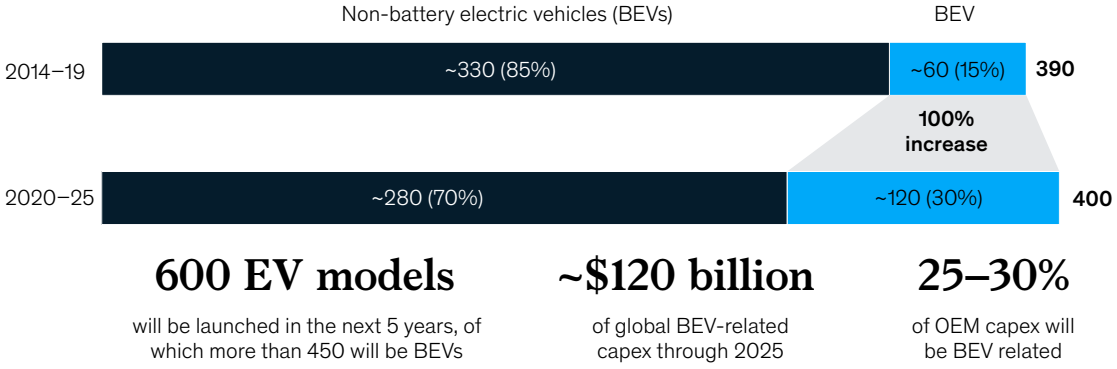
China, which accounted for 50 percent of BEV sales in 2019, is now the largest market. But OEMs in many countries are aggressively pursuing opportunities in this space, as shown by their recent model introductions and announcements, and sales are rising in most regions. According to recent McKinsey analysis, global BEV-related capex spend could increase to about $120 billion over the next five years (Exhibit 2).[1]

Despite the increased demand, OEMs will find the path to BEV profitability challenging. In a recent McKinsey survey of stakeholders in BEV production, only 18 percent of respondents expected a profit margin above $3,000 per vehicle; equally concerning, more than half expected a margin of less than $1,000 per vehicle.[2] Overall, Asian OEMs had a more positive profit outlook (Exhibit 3). Their upbeat projections may be partly explained by China's higher incentives, which allow OEMs to price BEVs more aggressively, or by the cost reductions that many Chinese OEMs have obtained by producing BEVs on modified internal-combustion-engine (ICE) platforms.

Exhibit 2

Capital expenditures for BEVs will likely double over the next five years, while investments in other vehicles decline.

Cumulative global model-related capital expenditures (capex), $ billion



600 EV models
will be launched in the next 5 years, of which more than 450 will be BEVs

~$120 billion
of global BEV-related capex through 2025

25–30%
of OEM capex will be BEV related

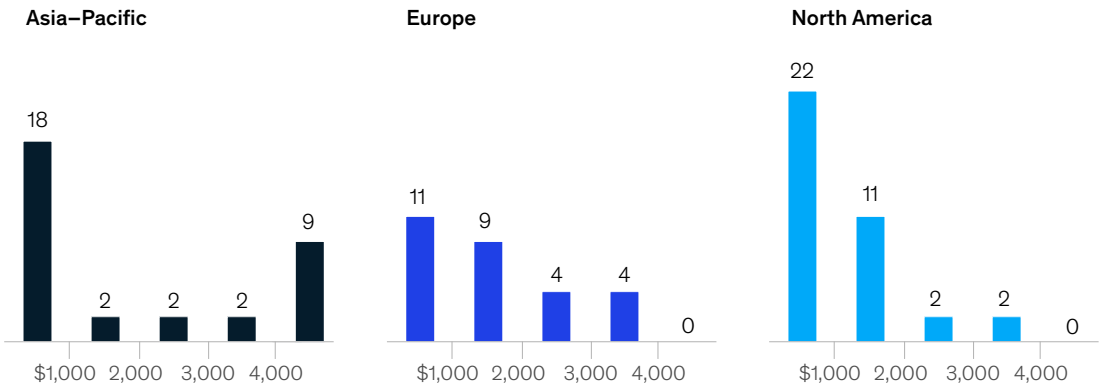
Note: Figures may not sum to 100%, because of rounding.
Questions: How has the coronavirus (COVID-19) situation affected your company's production (operation) capacity? How has the coronavirus (COVID-19) situation affected demand for your company's products/services?
Source: McKinsey COVID-19 B2B Decision-Maker Pulse #2, April 20–27, 2020 (n = 607)

[1] Our capital-expenditure (capex) projections for 2020 through 2025 were derived from calculations that factor in engine-production forecast data for battery electric vehicles from IHS Markit's "Light vehicle engine production forecast" for November 2019. Please note that while the production forecast data is from IHS Markit, the capex projections for 2020 to 2025 here and in Exhibit 2 were developed by McKinsey and are neither associated with nor endorsed by IHS Markit.
[2] McKinsey Survey on BEV production, spring 2020, McKinsey.com

Exhibit 3

OEMs believe they will have difficulty achieving a profit with BEVs.

Expected profit margin, by region, $ per battery electric vehicle, % of total respondents[1]



Globally, OEMs have averaged 7% annual profit across all vehicle types over the past 7 years. A 7% profit corresponds to an approximately $2,800 profit margin.

[1]100% = 45 respondents (15 from Asia–Pacific, 13 from Europe, and 17 from North America).
Source: McKinsey Survey on BEV production (Spring 2020)

Levers for reducing BEV costs

With profitability uncertain, cost reduction is a priority. While OEMs should certainly minimize variable costs for BEVs whenever possible, they must also find opportunities to reduce fixed costs in three areas. First up is R&D. The product-development process for a new model takes about three years—33 to 38 months—even though BEV designs are simpler than ICE designs. This extended time frame ties up significant engineering resources that compete with ICE portfolios. If companies can improve R&D efficiency and reduce timelines, they can directly reduce vehicle costs The second major area is manufacturing. An OEM's existing footprint is typically complex. Building a one-size-fits-all dedicated BEV production line requires substantial investment. With volume uncertainties, amortized capex can exceed $1,000 per vehicle. Taking a more flexible manufacturing approach can allow companies to defer investment until volumes ramp up. Finally, batteries, e-drive, and other BEV components add significant cost to the final product. To keep expenditures in check, companies need to reconsider their make-versus-buy decisions for all systems and components.

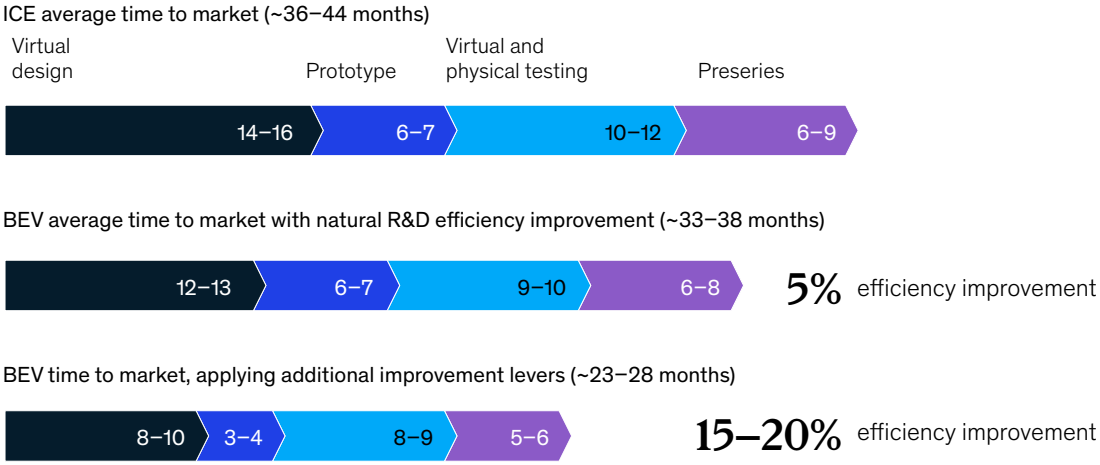
R&D excellence

OEMs have made significant leaps in ICE R&D efficiency over the past 40 years. Time to market has fallen substantially, going from 55 to 65 months in the 1980s to 36 to 44 months today, thanks to virtual simulation, design tools, and prototype-tooling technologies. With their simpler powertrain configurations, less complex manufacturing processes, and the elimination of extended emission testing, the time to market for BEVs is already about three months shorter than that for ICE vehicles, potentially making the R&D process about 5 percent more efficient (Exhibit 4).

Exhibit 4

OEMs have the opportunity to achieve additional cost reductions within R&D for BEVs.

Comparison of ICE and BEV program,[1] product-development timelines, months



[1]For mass-market internal-combustion-engine (ICE) compared with passenger battery-electric-vehicle (BEV) above 150,000 units annually only, exclusive of commercial or industrial vehicles.
Source: McKinsey Survey on BEV production (Spring 2020)

Our BEV benchmarking shows that many Chinese OEMs have already benefited from targeted cost allocation to areas most interesting to local consumers. One example is the strong focus on providing appealing user features and integrated experiences on the human-machine interface system. The majority of Chinese OEMs also leverage existing platform designs, often stemming from ICE architectures, which not only speaks to their focus on local consumer interests but also can unlock additional R&D efficiencies. But OEMs can achieve even more R&D gains by applying four levers related to platform modularity, agile processes, virtual prototyping, and complexity management. Together, these levers could improve R&D efficiency by an additional 15 to 20 percent and decrease time to market by up to ten months.

Platform modularity. While Chinese players mainly use shared or modified ICE or xEV platforms to help boost production volume, other OEMs prefer native BEV platform designs that provide higher battery capacity and longer range. For second-generation native BEVs, a "skateboard" type of modular design can further unlock significant R&D efficiency gains.[3]

Agile processes. Beyond architectural and platform changes, OEMs can improve R&D efficiency by implementing vehicle-program-centric agile development processes. Agile processes, such as quick iterations and trust/delegation, can increase R&D productivity by 20 percent, reduce time to market, and decrease warranty expenses by 30 to 50 percent.

Virtual prototyping. Virtual validation and testing will help shorten time to market, leading to greater profitability by reducing expenses for physical prototyping and testing. Done well, virtual development can reduce the expense of redesigns and tool changes for problems found during preseries launch. Eventually, virtual prototyping may completely replace physical prototyping.

[3] "Skateboard" is an industry term that implies one platform design (chassis/e-powertrain/thermal) can be easily fitted to multiple uniquely designed upper bodies.

Complexity management. OEMs may also decrease R&D timelines by taking a new view of product differentiation that involves placing limits on the number of hardware combinations to manage complexity. For instance, they might differentiate products based on software, including over-the-air options, rather than hardware features.

Flexible manufacturing

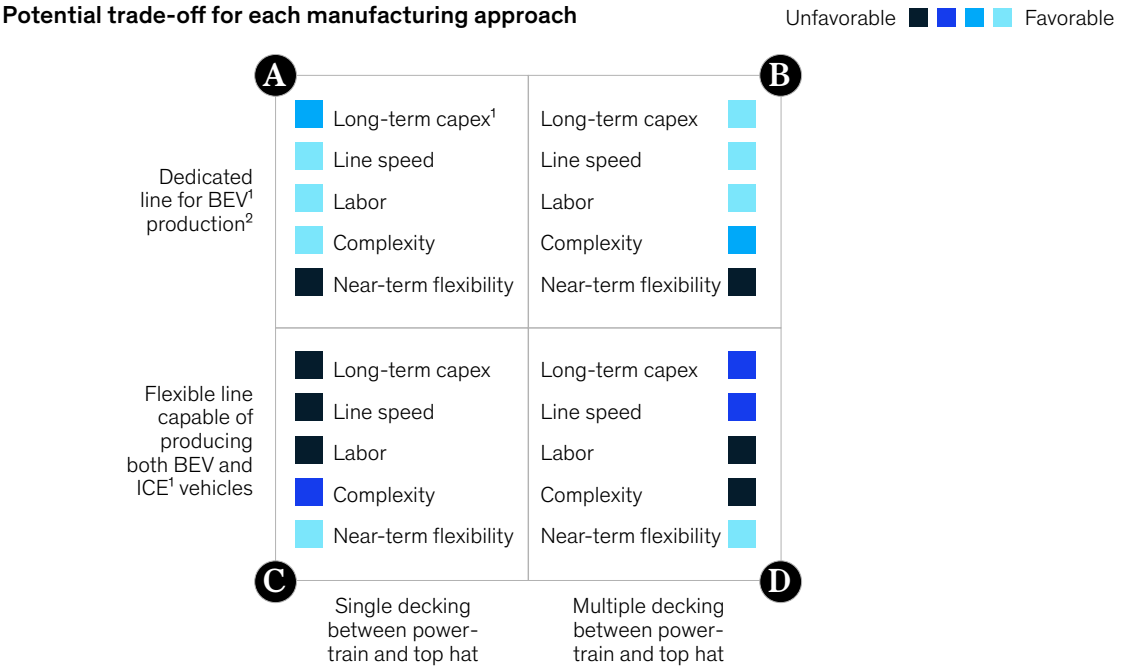
When it comes to BEV manufacturing and assembly, OEMs face two major decisions (Exhibit 5). First, they must opt for either dedicated or flexible assembly lines. While a dedicated line can increase speed, reduce labor, and minimize complexity, flexible lines allow companies to adjust production quickly and at low cost over the near term. That said, flexible lines are associated with higher long-term capex than dedicated lines. The other big decision involves choosing between a single-or multiple-decking approach to connect the e-powertrain and the vehicle's upper body structure, often called the "top hat." With a single-decking approach, the front chassis module, rear chassis module, and battery pack are decked at one station. In a multiple-decking approach, these systems are typically at three separate stations to reduce complexity.

To date, OEMs have taken various approaches when launching BEV models. When an OEM achieves scale in a region (production of more than 150,000 vehicles annually), a dedicated BEV line with a single decking point between the skateboard and top hat is likely the best option. In North America, building a new dedicated BEV assembly line by converting an old ICE plant makes the most economic sense, even for start-up OEMs. Compared with launching a new ICE model on an existing ICE line, launching a new BEV on a converted ICE line would require about 10 percent additional capex.

Exhibit 5

Each OEM must consider trade-offs associated with different line and decking approaches.

Potential trade-off for each manufacturing approach



[1]BEV = battery electric vehicle; ICE = internal combustion engine; capex = capital expenditures.
[2]Total long-run capex required for brownfield conversion of an existing ICE assembly line to a BEV-only line.

There are sometimes advantages to flexible lines and a multidecking approach. For instance, flexible lines allow most OEMs to avoid a high up-front capital commitment when BEV volumes are low, but still give them the option of ramping up production later. Generally, OEMs can easily integrate well-planned flexible lines with existing ICE lines after making minimal floor-plan overhauls. Typically, flexible lines allow OEMs to defer up to 25 percent of the required capex investment until volume ramps up—a benefit not possible with dedicated lines (Exhibit 6). With multidecking, the advantages arise because this approach allows for more efficient assembly. For instance, OEMs can install batteries after BEVs roll off the main line, reducing capex by 5 to 10 percent while improving line speed.

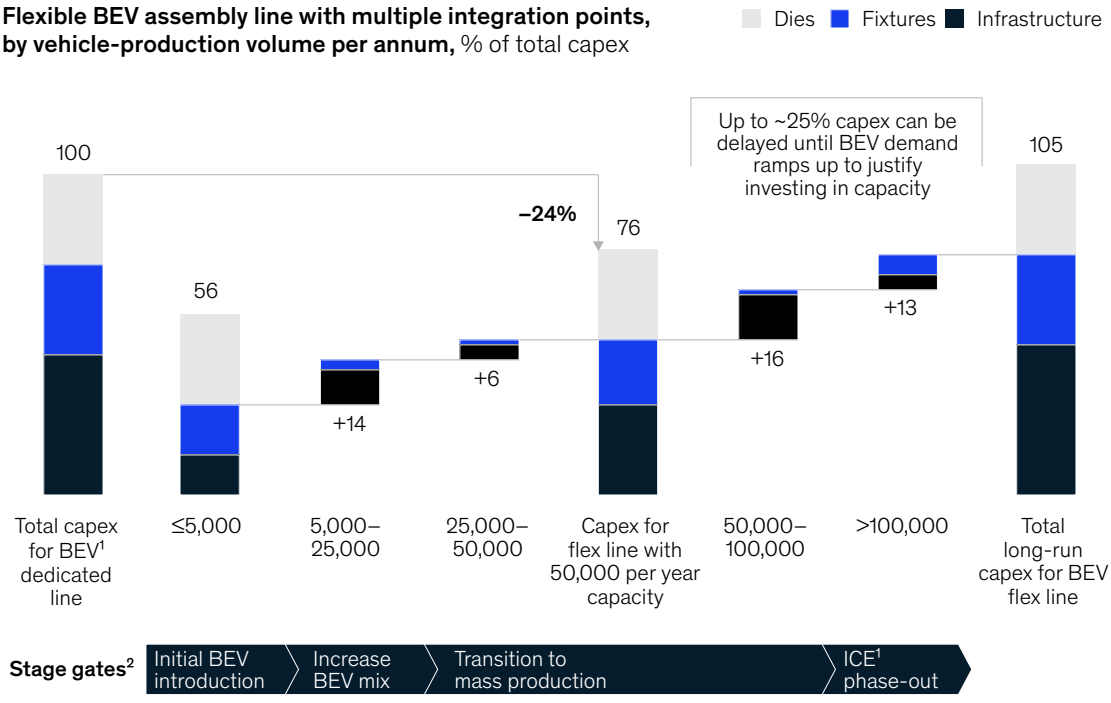
No single manufacturing option is optimal for every company. Based on an OEM's projected volume, footprint, and product portfolio, one approach could trump the others and create the most economic value. What's important is that OEMs thoroughly consider each option in light of their unique circumstances.

In addition to selecting the appropriate line and decking approach, OEMs can optimize production costs by focusing on customer segments during vehicle design and specification.[4] They can also find savings by using or reusing industry-standard parts and carryovers. Finally, a design-to-cost or design-to-value approach can reduce expenses for the e-powertrain.

Exhibit 6

Flexible lines allow OEMs to defer some capital expenditures while making it easier to adjust production.

Flexible BEV assembly line with multiple integration points, by vehicle-production volume per annum, % of total capex



[1]BEV = battery electric vehicle; ICE = internal combustion engine; capex = capital expenditures.
[2]Capex stage gates for a flexible BEV assembly line with multiple integration points.
Source: Expert interviews; McKinsey analysis

[4] Mauro Erriquez, Philip Schäfer, Dennis Schwedhelm, and Ting Wu, "How to drive winning battery-electric-vehicle design: Lessons from benchmarking ten Chinese models," July 10, 2020, McKinsey.com.

Value-chain integration

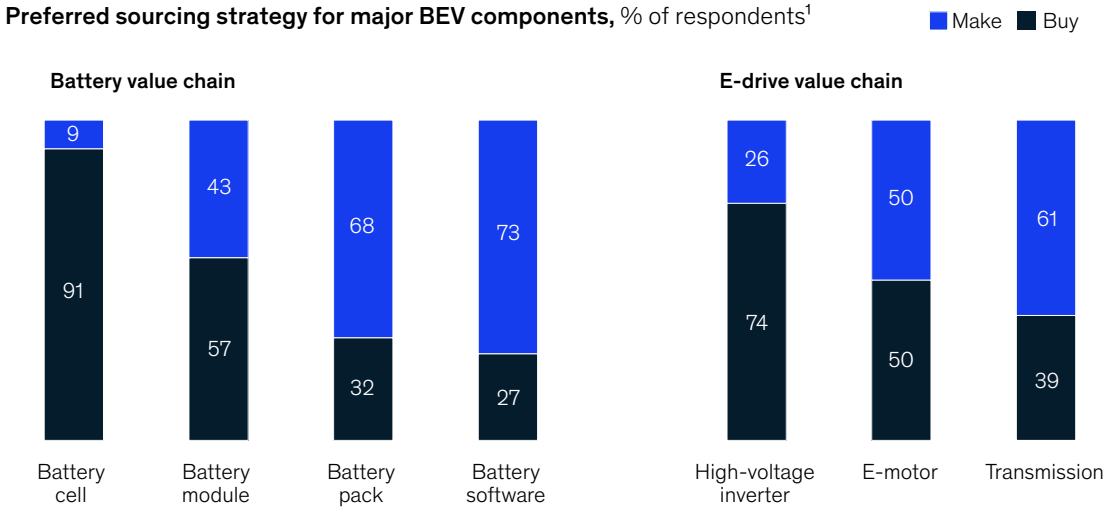
With advances in BEV technology, the battery market will likely reach $100 billion in size by 2025, while the e-drive market will likely reach $30 billion.[5] Within the battery value chain, most OEMs buy single components, such as battery cells, but prefer to keep software development and many other integration and assembly tasks, such those for battery packs, in-house. With e-drive, a similar pattern occurs, with most buying high-voltage inverters while outsourcing transmissions. For e-motors, OEMs are equally divided between in-house production and outsourcing (Exhibit 7).

As they increase BEV production, OEMs should reevaluate their value-chain strategy, including their make-versus-buy choices for both battery and e-drive components. Their assessments should consider seven factors: organizational focus, internal innovation capabilities, the degree of uncertainty regarding demand and technological advances, capex and other economic issues, production speed, external constraints, and the desire for production control. If an OEM has never manufactured battery cells, for instance, it may need to make a significant investment in talent and facilities before moving into this area. Some external constraints may also complicate matters, such as the need to convert ICE plants into BEV facilities to create the battery cells. These factors must be weighed against the benefits of in-house production, such as the ability to secure a steady supply of high-quality battery cells.

Each OEM may reach different conclusions from such analysis. That said, an OEM with a typical production volume of under 50,000 vehicles annually will likely find it most cost-effective to buy battery cells, e-motors, and inverters while keeping integration and assembly of battery modules and

Exhibit 7

OEMs now pursue different sourcing strategies for each component.



Question: What is your preferred sourcing strategy for each of the major BEV components (make vs buy)?
[1]100% = 45 respondents (17 from North America, 13 from Europe, and 15 from Asia–Pacific).
Source: McKinsey Survey on BEV production (Spring 2020)

[5] McKinsey Reboost! model. Battery includes battery cell, module, pack, and battery management system (BMS). E-drive includes e-motor and high-voltage inverter.

packs, as well as battery software development, in-house. As volumes increase, it may become more advantageous to in-source more components. Here's what we found to be true for most players:

— *Battery value chain.* The typical OEM will gain a financial advantage by making its own battery packs when production volumes exceed 50,000 in a region. However, it will need to produce more than 100,000 vehicles to gain a financial advantage from the in-house production of battery modules. In addition to increasing gross margins, in-sourcing battery pack and module assembly allows OEMs to ensure that the interface between the battery and vehicle is working properly. In addition, in-sourcing would allow that some workers from ICE production lines could be reskilled for BEV powertrain assembly. For battery cells, the size must exceed 15 gigawatts or production must exceed 500,000 units in a region to achieve manufacturing efficiency and ensure profitability. Otherwise, OEMs may never recover their high R&D investment.

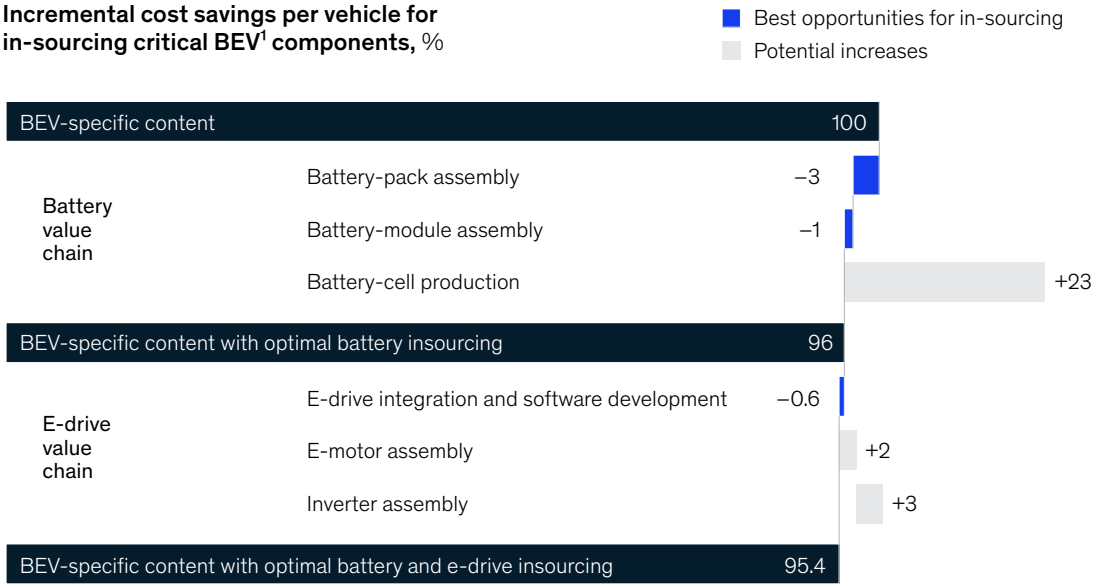
— *E-drive systems.* In this area, cost will be the major differentiator. BEVs that scale first will have lower costs. For performance, software will be the main differentiator, with periodic upgrades potentially increasing an OEM's competitive advantage. In consequence, the typical OEM will benefit from buying e-drive components and then integrating them in-house. It will also benefit from keeping software development in-house, since it will have more control over the type and frequency of upgrades. We do not expect an increase in BEV volumes to have a major influence on make-versus-buy decisions for e-drive systems.

The sidebar, "Make-versus-buy decisions," shows what the typical OEM will consider when deciding whether or not to in-house production of specific components.

A revised approach to value-chain integration can yield big rewards, such as reductions of up to 4 to 5 percent in the cost of BEV-specific content, including the battery and e-drive (Exhibit 8). Total vehicle costs might fall by 2 to 3 percent.

Exhibit 8

For a typical OEM, vertically integrating assembly of battery packs/modules and integrating the e-drive system create the most value.



[1]BEV = battery electric vehicle.

Make-versus-buy decisions

A close examination of seven factors in make-versus-buy decisions shows that for the battery value chain, production volume is an important consideration when making decisions about in-sourcing battery cells, packs, modules, and battery-management systems (Exhibit A). For the e-drive value chain, the typical OEM will benefit from buying e-motors and converters while leaving integration and software development in-house (Exhibit B).

Exhibit A

For the battery value chain, make-versus-buy decisions vary by component.

Factors influencing make-versus-buy decisions[1]

Buy ●●●●●●● Make

	Battery pack and BMS[2]	Battery module	Battery cells
Organizational focus	● Additional R&D resources needed for in-sourcing battery-pack assembly	● Need resources for pack assembly and module creation	● Huge internal effort required to build battery-cell R&D and manufacturing capabilities
Uncertainty	● Uncertain future BEV[2] demand; pack technology unlikely to change significantly	● Uncertain future BEV demand; module technology unlikely to change significantly	● Uncertain future BEV demand; unpredictable advances in battery-cell technology
Economics	● Significant gross margin captured, offset by capital expenditures (capex) and R&D required	● Significant gross margin captured, offset by capex and R&D	● Very large initial capex investment and R&D for a low-margin product
Speed	● Pack directly interfaces with vehicle and will have faster time to market if made internally	● Module does not directly interface with vehicle; vehicle changes unlikely to translate to module	● Given equal cell-manufacturing capabilities, in-housing would enable faster time to market
Innovation	● OEMs can better design battery-pack form, fit, integration	● Module innovation likely to come from improved thermal/BMS; suppliers excel there	● OEMs are unlikely to create innovative battery technologies and are better off licensing them
External constraints	● Can absorb over 400 workers after existing ICE[2]/transmission plants are converted	● Can absorb an additional 50–100 workers incremental to those for pack assembly	● Can absorb more than 1,000 workers from converted ICE/transmission plants
Control	● Control over design and integration; reliant on having module from upstream	● Reliant on steady supply of high-quality cells from upstream	● Ability to ensure steady supply of high-quality battery cells
Overall score	● Make if production volume ≥50,000/year	● Make if production volume >100,000/year	● Buy until production volume >500,000/year

[1]The typical OEM will gain a financial advantage by making its own battery packs and BMS when production volumes exceed 50,000 in a region. It will need to produce over 100,000 vehicles to gain a financial advantage from the in-house production of battery modules. For battery cells, the size must exceed 15 gigawatt-hours or production must exceed 500,000 units to gain a financial advantage.
[2]BMS = battery-management system.

Make-versus-buy decisions (continued)

Exhibit B

For the e-drive value chain, it is typically preferable to buy e-motors and inverters while leaving integration and software development in-house.

Factors influencing make-versus-buy decisions

Buy ●●●●●●● Make

	E-motor	Inverter	Software development and integration
Organizational focus	New R&D capabilities and management resources needed for design and integration	New R&D and electrical-component manufacturing capabilities likely required	Powertrain design and integration is already a core competency of OEMs
Uncertainty	E-motors use expensive raw materials, and there is still room for improvement	Inverters are highly commoditized, except for form and fit, and this is unlikely to change	Uncertain demand for BEVs; little uncertainty on manufacturing process
Economics	Current supplier margins and capex requirements slightly favor 'buy'	Potential for high margins, but large required R&D investment drags down returns	BEV powertrain assembly can be done on existing ICE[1] powertrain lines
Speed	Limited technological innovation; specialized suppliers likely enable faster time to market	Limited technological innovation; specialized suppliers likely enable faster time to market	Time to market for new powertrain platforms will be faster if done internally
Innovation	E-motor material innovations are more likely to come from e-motor manufacturers	OEMs without competencies in electronics will likely not be able to innovate	OEMs can apply ICE powertrain know-how to BEVs
External constraints	OEMs can save hundreds of jobs by adding e-motor assembly line	OEMs can save jobs by adding inverter assembly line	OEMs can save hundreds of jobs by converting existing ICE/transmission plants
Control	Control over e-motor design and production may be a differentiator	Control over supply chain is convenient but not essential; no risk of supply shortage	Platform design and efficiency will be a key differentiator for BEVs
Overall score	Buy	Buy	Make

The need for partnerships

Most OEMs do not have all the required capabilities, such as the ability to develop software for both batteries and e-drive, to move BEV production completely in-house. Consequently, they often need to form strategic partnerships across the ecosystem, including those for BEV design, manufacturing, and component sourcing. These partnerships will also allow them to share the burden of capex spending until they achieve sufficient scale.

Partnerships can take many forms, such as joint ventures, and OEMs may form links across the value chain, such as those with battery suppliers.

These partnerships may have various goals, from securing a supply of high-quality lithium-ion battery cells to codeveloping vehicles to building a supporting charging infrastructure. Managing such partnerships will require close attention and the ability to lead a complex network.

BEV profitability will continue to face headwinds from high e-drive and battery costs, as well as the need for high investments at a time when sales volumes remain challenged. By focusing on additional cost reductions in R&D, manufacturing processes, and value-chain integration, companies may realize profitability and put themselves in a stronger position as the BEV market gains traction.

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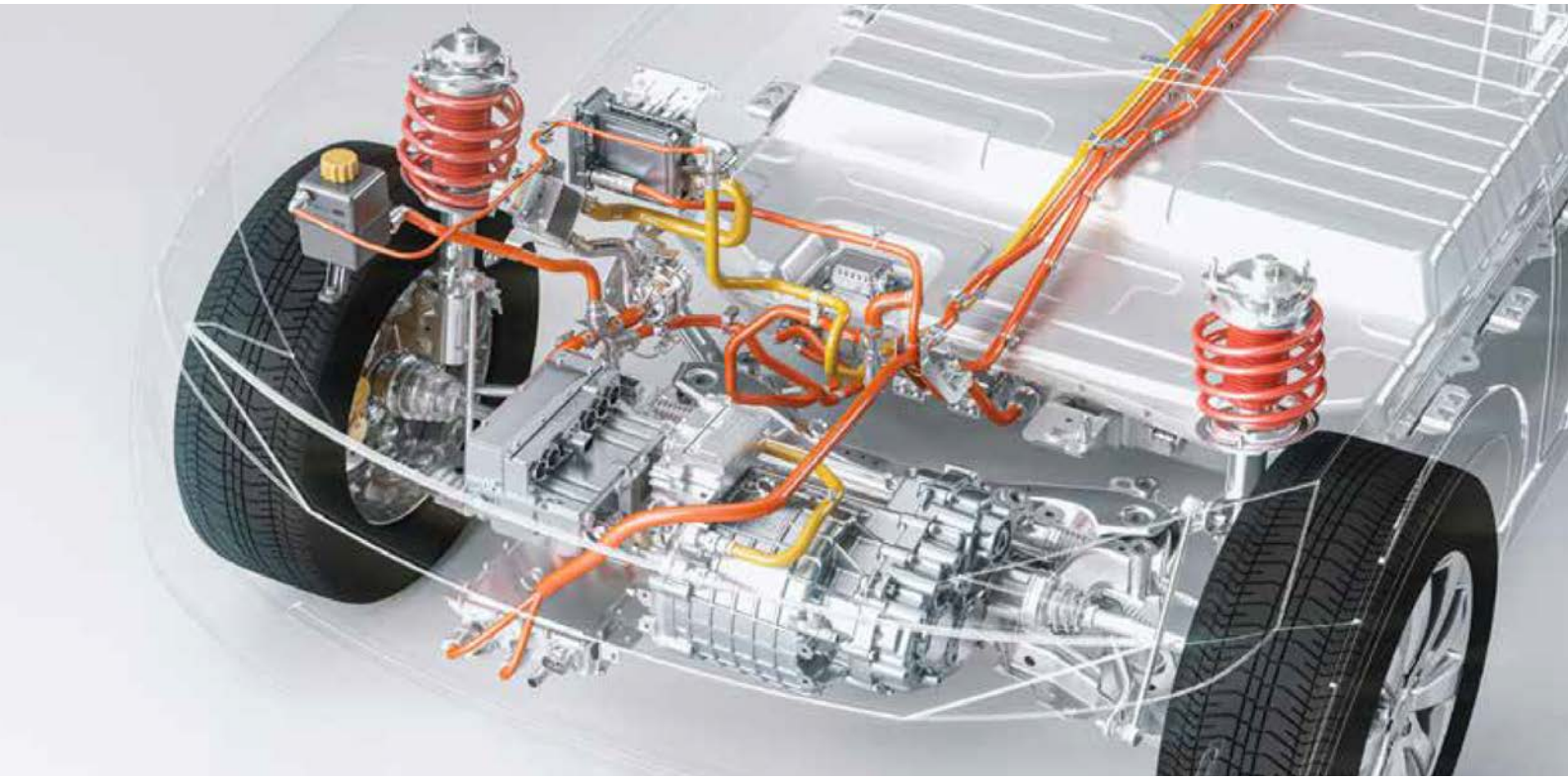
How to drive winning battery electric-vehicle design: Lessons from benchmarking ten Chinese models

Chinese OEMs use existing concepts and manufacturing technologies, as well as off-the-shelf components and a high level of modularization, for battery electric vehicles.

June 2020
by Mauro Erriquez, Philip Schäfer, Dennis Schwedhelm, and Ting Wu



Many automotive OEMs and suppliers in Europe, the United States, and Japan are starting large-scale launches of battery electric vehicles (BEVs) in their core markets. But in China, a rapidly growing BEV market and ecosystem have already emerged.

To help global automotive OEMs and suppliers truly understand the major challenges and opportunities of the Chinese BEV market, we analyzed ten BEVs that are popular in China in depth. We covered a large portion of the market, looking at vehicles from both incumbent OEMs and new players, including Buick, BYD, GAC, Geely, JAC, NIO, Roewe, SAIC, and Weltmeister. The companies included in our analysis cover 45 percent of the market with their complete BEV and EV portfolio.[1] The benchmarking consisted of a detailed technical analysis, as well as a cost estimate down to the level of individual components.

Our research on the Chinese market and our analysis of the benchmarked BEVs yielded the following insights:

1. The Chinese BEV market—dominated by Chinese OEMs, which had a market share of approximately 85 percent in 2019—is growing not only as a result of subsidies and regulations but also the increasing attractiveness of these products to customers.
2. For first-generation BEVs, many Chinese OEMs are focusing on low capital expenditures (capex) and a fast time to market , together with an ecosystem dominated by local suppliers. They use existing concepts and manufacturing technologies, as well as off-the-shelf components and a high level of modularization for pre-assembly. This approach creates a potentially profitable business case for at least some of the benchmarked BEV models.
3. Differences among e-powertrain designs (including e-drive,[2] power electronics, and battery systems), electrical/electronic architectures (E/E), and pricing models of the benchmarked BEVs indicate that there are still significant design- and cost-improvement opportunities.

1. China—the world's largest automotive profit pool—is quickly moving toward e-mobility

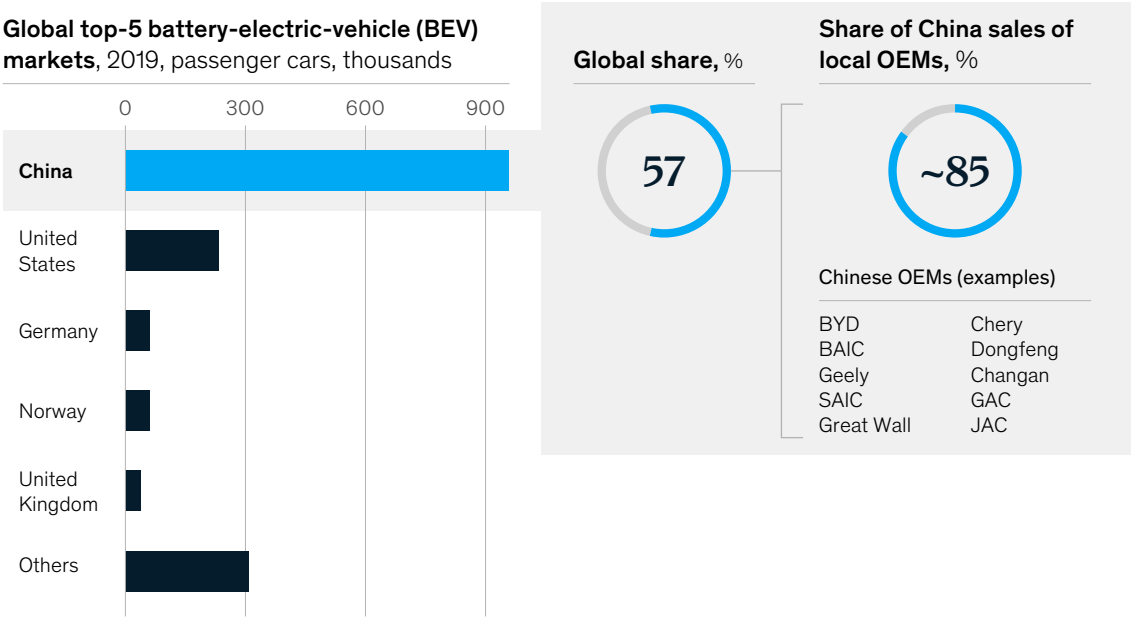
The Chinese automotive market is the world's largest automotive profit pool, accounting for one-third (about $40 billion[3]) of the global total. The market is now shifting toward e-mobility. From 2014 to 2019, BEV unit sales in China increased by 80 percent a year. With more than 900,000 units in 2019, 57 percent of the BEVs sold throughout the

In China, a rapidly growing battery-electric-vehicle market and ecosystem have already emerged.

[1] Calculation of total battery-electric-vehicle market share in China is based on EV-volumes.com's wholesale unit sales figures for China in 2019.
[2] An e-drive includes the e-motor, transmission, and inverter.
[3] This figure is derived from McKinsey's proprietary automotive-profit-pool model.

Exhibit 1

The Chinese BEV market, mainly controlled by local OEMs, is the world's largest, with a share of global volumes of more than 50 percent.



Note: Numbers are based on wholesale volume (similar to CAAM), which have generally been higher than the corresponding retail insurance volumes.

Source: EV-volumes.com; McKinsey analysis

world were sold in China, making it the world's largest BEV market. A look at OEM market shares reveals that Chinese OEMs dominate the market almost completely. International OEMs had a mere 15 percent of annual BEV sales in 2019 (Exhibit 1).

Looking back over the past few years, we see that BEV growth in China was triggered primarily by two factors:

— *Subsidies, quotas, and regulations facilitated production and adoption— and will continue to do so.* Early subsidies, along with the mandate that OEMs increase the share of BEVs in their portfolios, have been a significant driver of the greater availability and adoption of BEVs in China. In 2019, the reduction of subsidies slowed growth in demand, but China's CAFC[4]/EV credit rules still point to a percentage of EV penetration—mostly of BEVs—in the mid-teens by 2025.[5] Regulations on ride hailing and government fleets, as well as restrictions on traffic in city centers, will also keep up BEV demand.

— *The value proposition of BEVs is increasingly attractive to consumers.* Even though the decrease in BEV sales to individuals in 2019 showed that public policy still drives most of the demand for these vehicles, consumer-sentiment analysis shows more promising trends. The general perception of BEVs is exceptionally good regarding safety, performance, connectivity, and brands. Consumers know the

[4] Corporate average fuel consumption.
[5] See Robin Zhu, Luke Hong, Xuan Ji, *China EVs: Unique detail on Chinese EV sales by province and city, and buyer type*, Bernstein, February 13, 2020, bernstein.com.

financial and environmental advantages, and the driving experience stands out as the largest benefit of BEVs. Still, lingering concerns limit demand. Availability of charging infrastructure, cited by 45 percent of respondents, was the most significant concern.[6]

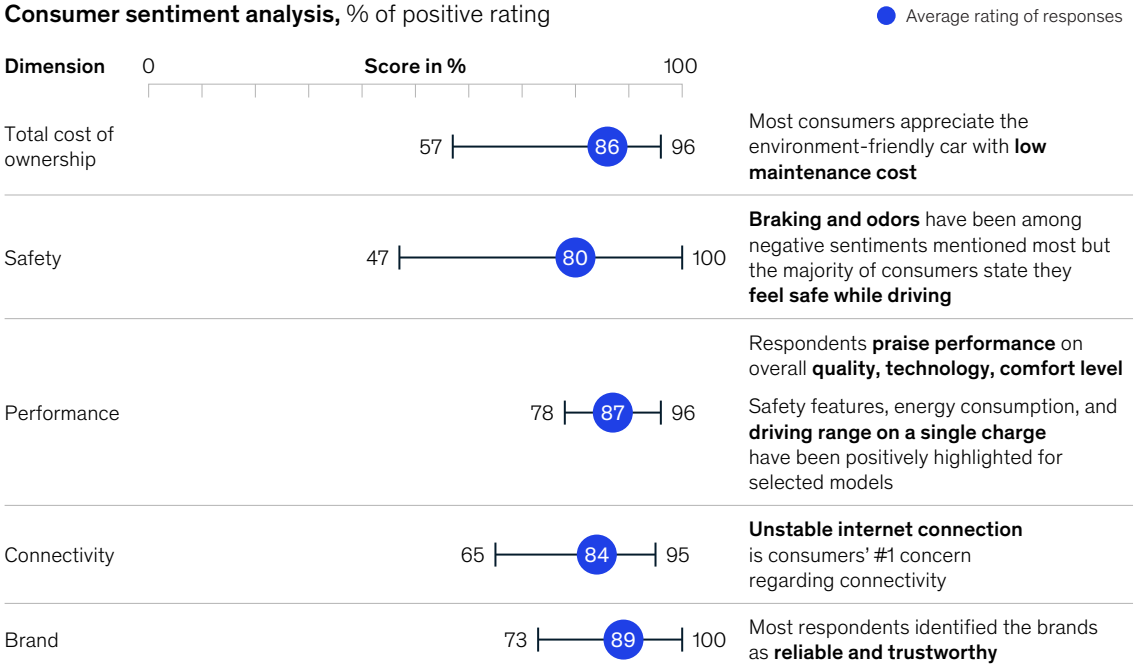
Many new models designed with Chinese consumers in mind have contributed to the acceptance of BEVs, which had a consideration rate of 80 percent in 2019.[7] Customer-sentiment analysis of the ten benchmarked vehicles shows that with an average approval rating of 85 percent, all OEMs have been able to tailor their products to the needs of customers (Exhibit 2).

All benchmarked vehicles perform like comparable European, US, or Japanese BEVs in absolute range or power but outperform them in range-to-price ratios (Exhibit 3). The tested Chinese BEV range is

[6] See findings from the McKinsey electric-vehicle consumer survey 2019, published in Thomas Gersdorf, Russell Hensley, Patrick Hertzke, Patrick Schaufuss, and Andreas Tschiesn, *The road ahead for e-mobility*, January 2020, McKinsey.com.
[7] Ibid.

Exhibit 2

Consumers largely acknowledge the performance of the ten benchmarked battery electric vehicles.

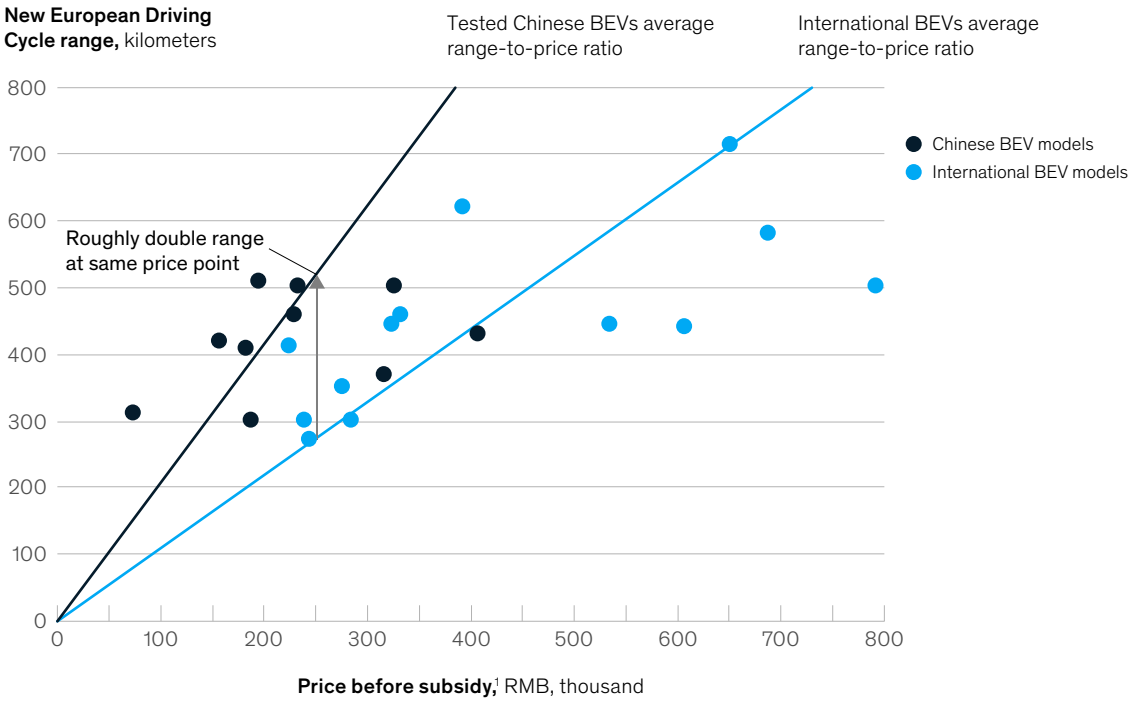


Source: McKinsey analysis

Exhibit 3

Compared with BEVs from established global OEMs, many Chinese models offer better range-to-price ratios.

Comparison between Chinese and international battery electric vehicles (BEVs)



[1] Due to launch timing and availabilities, prices of Chinese models are from official Chinese websites before subsidies whereas prices of international models are based on average Western markets.

Source: OEM website; press research; McKinsey analysis

nearly double that of international models at the same price points.

The outlook for the market is promising: BEV penetration in China is expected to grow from 3.9 percent in 2019 to 14 to 20 percent in 2025—a sales volume of roughly 3.8 to 5.0 million vehicles.[8] With the COVID-19 crisis affecting global BEV markets, China's central government decided in March 2020 to extend purchase subsidies by two more years to fuel BEV sales. Therefore, we expect that after stagnation in 2020—compared with the double-digit growth before COVID-19—the BEV market will pick up again, both absolutely and relatively, in 2021.

2. Chinese BEV producers are on the verge of becoming profitable, given sufficient volumes

Several BEVs have the potential to be profitable, as their product cost structures benefit from several unique characteristics of the Chinese market. The reuse of existing internal-combustion-engine (ICE)

[8] Figures are derived from McKinsey's proprietary Mobility Market Model and Sustainable Mobilty xEV Model.

platforms decreases time to market, and off-the-shelf components and a high level of modularization keep down capex. These design principles and their effects are supported by an ecosystem of local suppliers with long-established expertise across electronics and batteries.

Our bottom-up estimate of materials and production costs, based on more than 250,000 data points, reveals that nine out of ten vehicles may achieve a moderate to solid contribution margin of up to 50 percent. However, we estimate that a lower share may actually achieve a positive operating margin when we take into account warranties; selling, general, and administrative costs; R&D; and capex (Exhibit 4). The high variance in fixed costs can stem from various factors, such as the depth of integration and differences in sourcing strategies or the overall volume of OEMs.

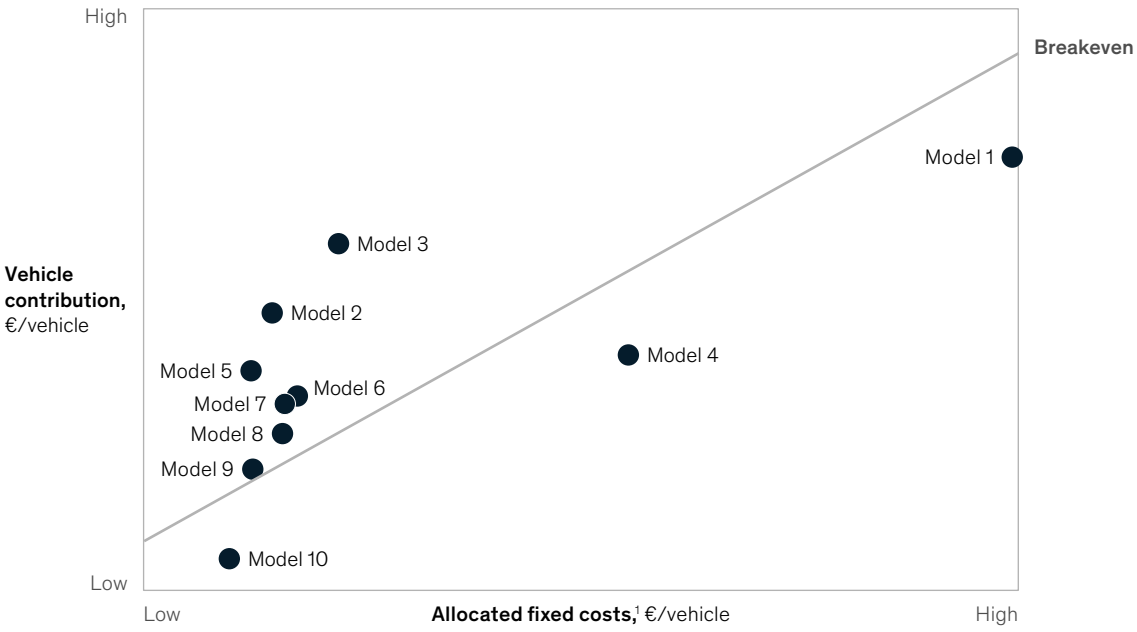
New market entrants in particular need to deal with structural challenges and low overall vehicle volumes. Together with further efforts to excel in R&D, the optimization of capex through flexible manufacturing and strategic value-chain positioning could help more OEMs turn a profit with their BEV models.

To offer a wide range of BEV products and models quickly, most Chinese BEV OEMs manufacture these cars by modifying their existing ICE platforms or using multipurpose shared platforms. We compared the designs of the vehicles during the physical teardown, leveraging our 3-D digital-

Exhibit 4

Battery electric vehicles from our benchmark set may be profitable after they ramp up to full volume.

Estimation



[1] Excludes any ramp-up cost.

Source: McKinsey analysis

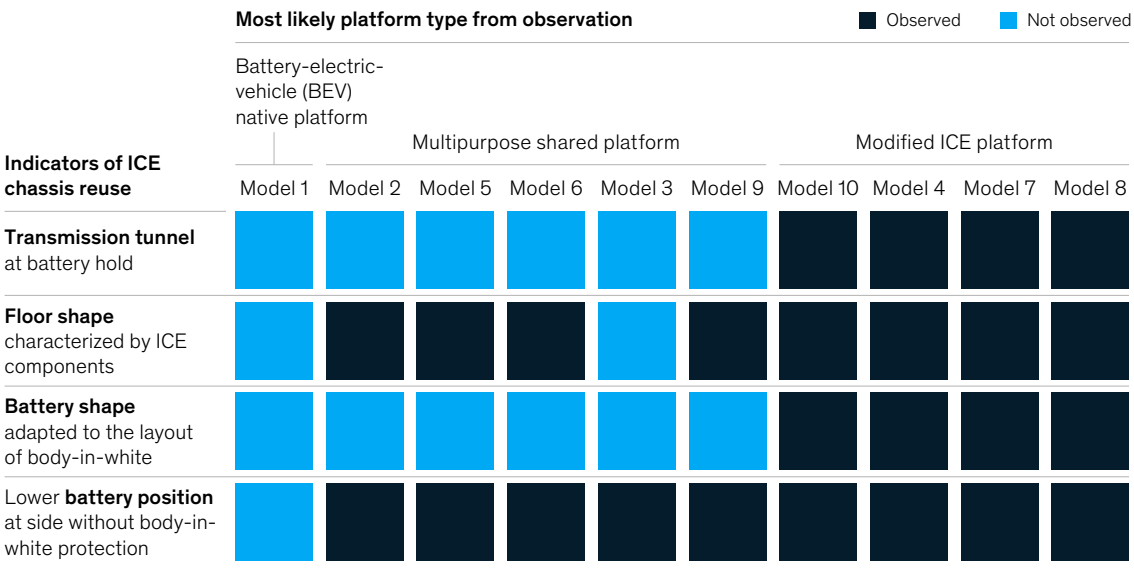
twin/virtual-reality software. This work showed that nine of the ten benchmarked BEVs share features such as battery shapes, battery positions, and floor shapes. That indicates the reuse of an ICE chassis and thus a modified or shared ICE platform (Exhibit 5). Likewise, the use of similar designs facilitates industrialization, since existing blueprints for processes and manufacturing technologies can be leveraged. Industrialization takes up a significant share of the product-development process, so this approach is essential for achieving short time to market.

In addition, we observed OEMs implementing a segment-focused design, focusing on existing concepts and manufacturing technologies, and using off-the-shelf components. These allow for reduced capex and rapid industrialization (Exhibit 6).

High modularization and outsourcing promote capex–efficient manufacturing. Once modularized, content can be pushed toward preassemblies and suppliers to increase the level of outsourcing, which permits a less complex mainline assembly process. In particular, we observed a high degree of assembly flexibility in three out of ten models: the e-drive and further power electronics (DC/DC-converter and onboard charger (OBC)) are preassembled on a subframe as one module. Moreover, the battery system can be built into the vehicle at any time

Exhibit 5

Body-in-white designs indicate the use of modified internal-combustion-engine (ICE) or shared platforms.



Source: McKinsey analysis

Exhibit 6

Many players use preexisting steel body-in-white, so the share of lightweight components is low.

Type of body-in-white		Descriptions
State-of-the-art aluminum body	Model 1	Full aluminum body with mostly nonthermal joining methods as well as usage of carbon-fiber reinforced polymer parts in trunk of vehicle
Modern steel body	Model 2, 5, 6	Fully automated body-in-white with aluminum share in closures and usage of, eg, high-strength steel for improved crash performance and reduced weight
Steel body optimized	Model 7, 8, 10	Full-steel body with mostly traditional joining methods (weld spots), but usage of optimized material concept (eg, hot-formed steel)
Traditional full steel body	Model 3, 4 9	Simple steel body using manual welding operations (especially in low-capacity lines)

Source: McKinsey analysis

Exhibit 7

The ten benchmarked battery electric vehicles used a variety of assembly-modularization approaches.

Modularized | Partially modularized | Individual component level

We see different archetypes of assembly modularization		E-drive (including axle)	Power electronics	Battery	High-voltage harness and tubing
Type 1 The front-axle integrator Widely spread modularization across key car components to simplify main-line assembly	Model 4, 8, 10	Preassembled module (on subframe)		Fully independent module (flexible integration throughout assembly process/ late integration possible)	Preassembled to main line with various connectors
Type 2 The electronics integrator Modularization of different electronics components	Model 1, 2, 5, 7	Self-supporting axle with simplified assembly rack; additional components assembled separately	Integrated module (eg, 1-box design)		Fully preassembled complete electronic module, 1-connector assembly in main line
Type 3 The component assembler Low level of modularization; complex assembly resulting in high capital and operating expenditures	Model 3, 6, 9		Single-component assembly	Early integration in assembly main line required	Individually assembled on main line

Source: McKinsey analysis

during assembly, providing for late integration and making assembly more flexible (Exhibit 7). This, in turn, further reduces capex demand.

Regarding fast industrialization, the current supplier ecosystem speeds up time to market. China's long-established expertise in electric machine production, semiconductors, electronics, and, especially, batteries makes it possible for local companies to supply all components of the e-powertrain (Exhibit 8). Depending on the level of vertical integration, OEMs source 45 to 100 percent of e-powertrain components from local suppliers.

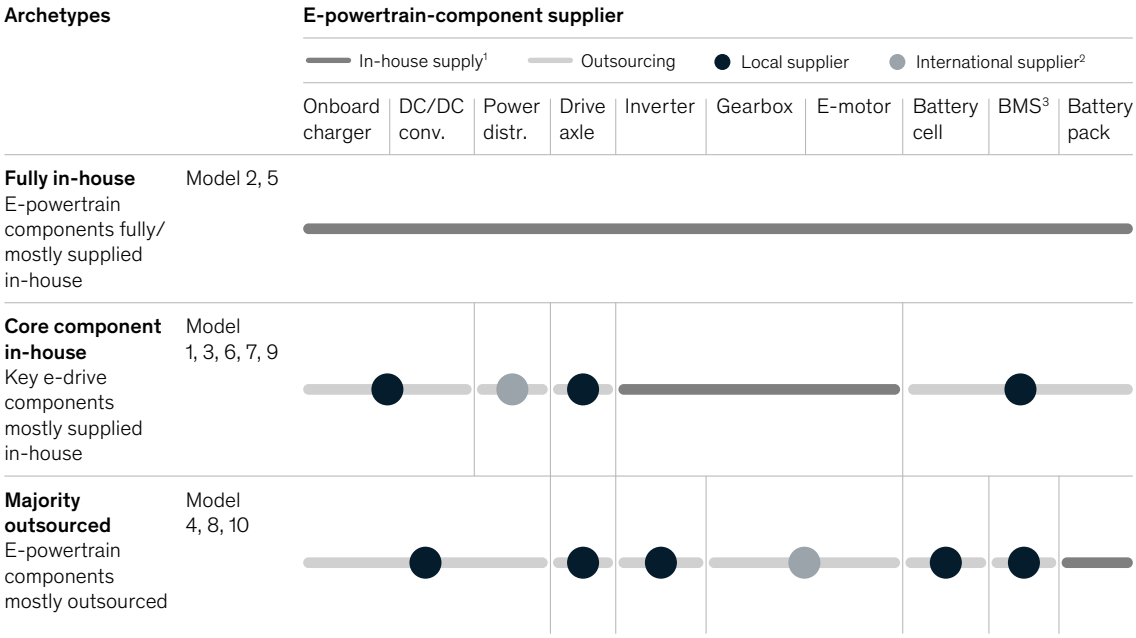
However, in the broader context—providing production equipment and setting up manufacturing lines—global players remain involved. The know-how of Western manufacturing-equipment OEMs enables Chinese suppliers to deliver the quality needed for the entire value chain, in paint shops, for example.

3. Substantial variety in design and technology remains—the game is far from decided

Local OEMs have demonstrated a position of strength in the Chinese BEV market, but a deeper look at the technology reveals that substantial differences across OEMs remain. Variations in three aspects of vehicles will influence the development of next-generation BEVs and may provide an opportunity for others to gain a foothold in the market.

Exhibit 8

Chinese OEMs rely heavily on local suppliers, with three archetypes of module integration.



[1] By OEM internally or by JV/subsidiaries supplier of OEM.
[2] Including joint ventures with international suppliers.
[3] Battery-management system.

Source: McKinsey analysis

E-powertrain. The benchmark revealed a large variety of concepts throughout the e-powertrain, such as the battery layout, the thermal management design and routing, and drivetrain-module integration. Our 3-D models show that half of the benchmarked models use grid and row layouts for the battery pack, increasing the utilization of space and, potentially, lowering module-production costs thanks to a lower level of packing variety than multiple-sized battery modules would require (Exhibit 9).

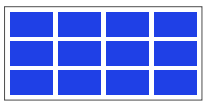
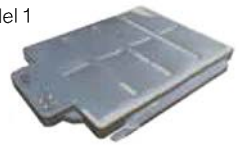
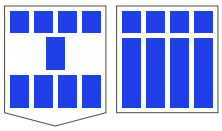
In addition, the degree of physical integration varies. Only three models show a high level of it: electric components and the e-drive are physically integrated, and the thermal management spans all components. Two models show the same level of physical integration, but the thermal management is separate for the e-drive and for the battery. The remaining models use less integrated components: separate electric modules and separate thermal management. Of these, three models use passive air cooling, which limits the charging speed when compared with the other models, which use liquid cooling of the battery (Exhibit 10).

E/E architecture. The benchmark shows that the weight of low-voltage wiring and harnesses differs among models with similar functionalities. That suggests significant design and cost-improvement opportunities in the E/E architecture. Similarly, OEMs of the benchmarked BEVs chose different ADAS[9] functionalities, use different designs for the electronic control unit (ECU) integration,

[9] Advanced driver-assistance system.

Exhibit 9

There are three designs for battery-pack module layouts, with implications for pack-space utilization and module packaging.

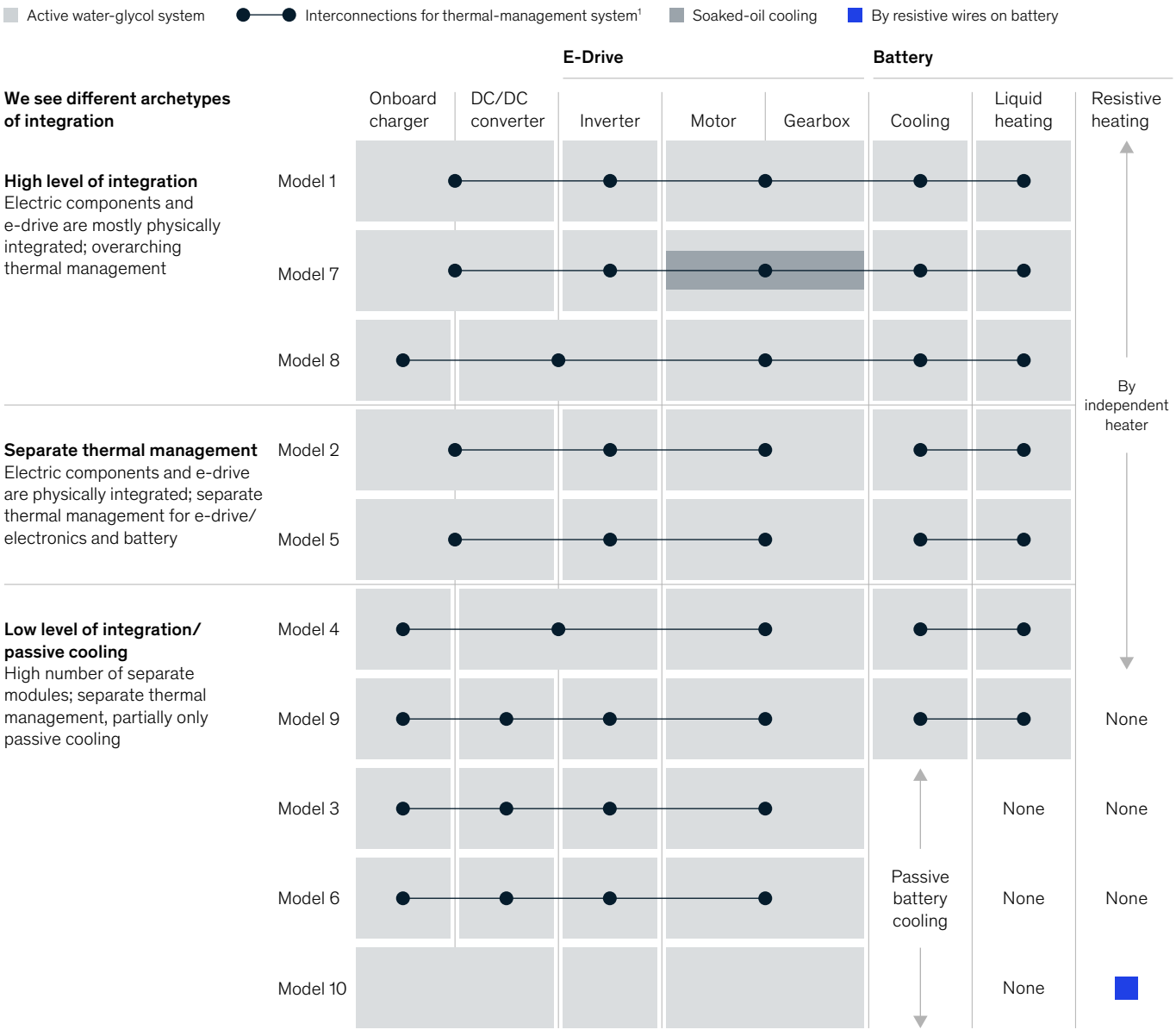
Module layout	Description	Test vehicles	Examples
Grid 	Identical sized and shaped module Layout in equally spaced grids	Model 1, 3, 9	Model 1 
Row 	Mostly identically sized and shaped modules Layout in equally spaced row	Model 2, 5	Model 5 
Adapt to pack shape 	Mostly multiple-sized and -shaped modules Arranged according to pack shape/varied module distance	Model 4, 6, 7, 8, 10	Model 7 

Source: McKinsey analysis

Exhibit 10

As with Western battery electric vehicles, there is no convergent powertrain design among Chinese BEVs—yet.

Comparison of powertrain and thermal management design



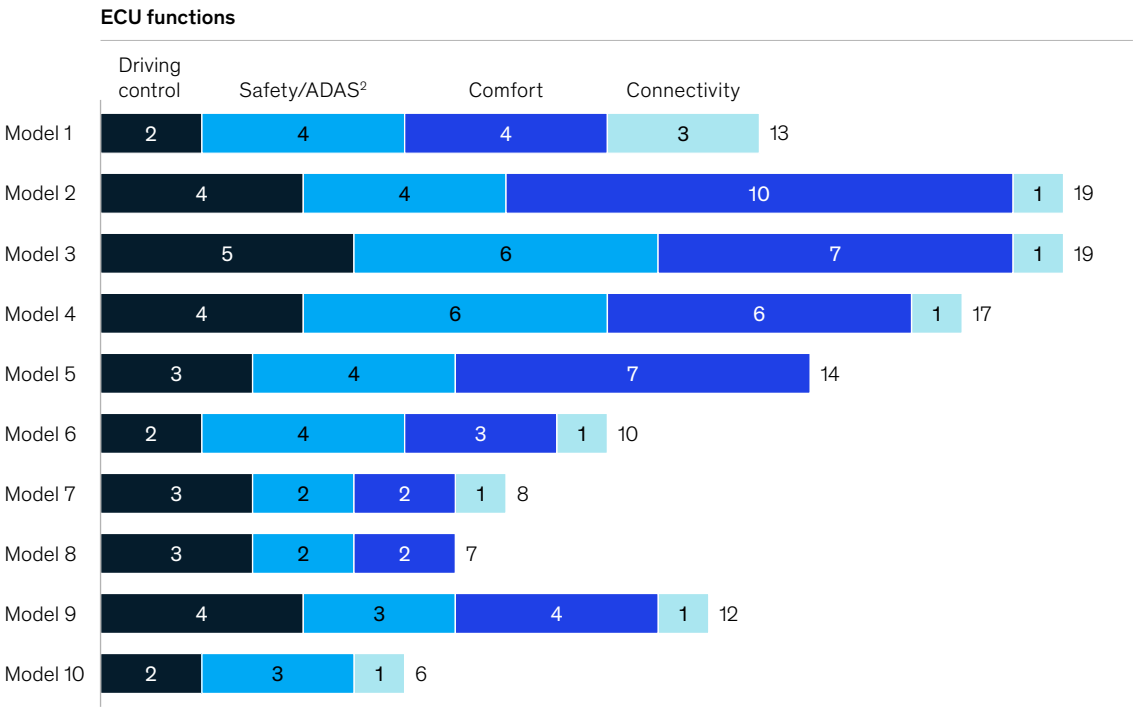
[1]Direct cooling jacket/pipeline/evaporator/heat exchanger connection.

Source: McKinsey analysis

Exhibit 11

Electronic-control-unit (ECU) usage is roughly correlated with design features, and some OEMs integrate ECUs in more sophisticated ways.

Low-voltage (LV) ECU function distribution, number of ECUs[1]



[1] ECUs of high-voltage system and chassis excluded.
[2] Advanced driver-assistance systems.

Source: McKinsey analysis

and differ in the number of ECUs used. The benchmarked BEVs have six to 19 decentralized ECUs (Exhibit 11). One potential direction would be to integrate all functions in one vehicle controller, as a BEV player in the United States does. That might increase performance at a relatively low cost but calls for substantial R&D investments and advanced internal software-development capabilities.

Trim packages. Chinese BEVs offer two to four trim packages on top of the base model. That reduces complexity and costs compared with the larger portfolio of options common among Western OEMs.

Seven out of ten benchmarked models therefore have a price spread of less than 50 percent between the base models and the fully loaded ones (Exhibit 12). Five out of ten offer battery or motor upgrades independent of the trim package, and three offer priced exterior options, such as color and wheels. Consequently, there might be untapped revenue potential in pricing strategies or non-hardware revenues, such as over-the-air software updates. Overall, global automotive OEMs may use our findings as a signal to simplify their portfolios or as a point of differentiation, especially when they think about entering the Chinese market.

4. Several strategies can help companies be successful in the market

Given the dynamic environment, succeeding in the Chinese BEV market presents significant uncertainties. Yet international OEMs and suppliers cannot afford to miss out on the Chinese BEV market in the long term, considering its sheer size and opportunities. In contrast, Chinese players will need to secure their dominant position and continue to focus on profitability.

The insights gained through the benchmark indicate several trends in the Chinese BEV market, each pointing to an associated strategic action or opportunity.

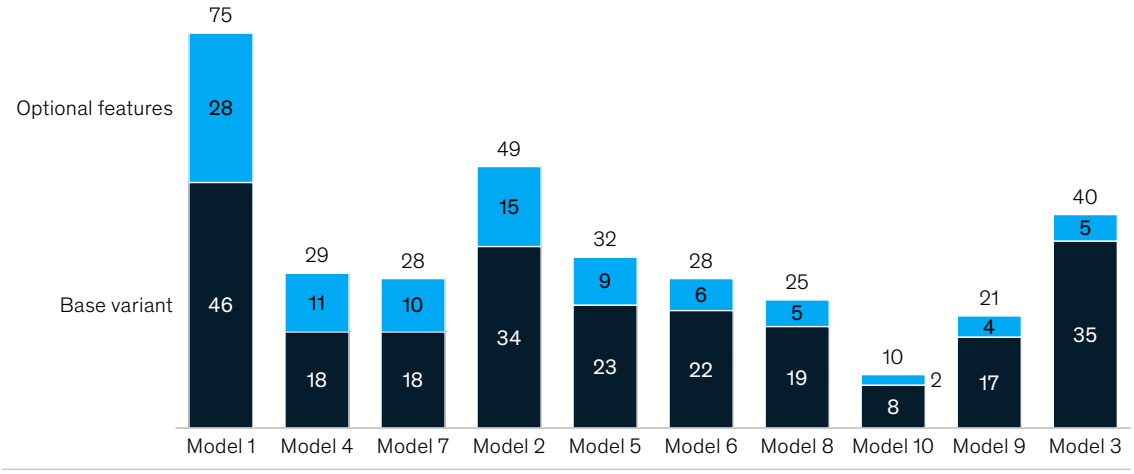
Development cycles are accelerating. To increase profitability and achieve a competitive advantage, OEMs are speeding up the development cycles of their BEVs. For current (and mostly first-generation) models, OEMs have cut time to market by reusing or modifying existing ICE platforms and relying on off-the-shelf components. But it is expected that for the next generation of BEVs, time to market will continue to fall as more OEMs develop dedicated BEV platforms and produce higher volumes. In addition to reducing time to market, the higher volumes will convey cost and design advantages.

The market composition will probably change. There are now around 80 BEV brands in China owned

Exhibit 12

Battery electric vehicles have a low price spread between the base and the fully loaded model.

Price of vehicle base variant and optional add-up, € thousand



	Model 1	Model 4	Model 7	Model 2	Model 5	Model 6	Model 8	Model 10	Model 9	Model 3
Additional price for fully loaded model compared with base variant	61%	61%	53%	44%	38%	30%	27%	27%	23%	15%

Source: McKinsey analysis

by about 50 companies. Of these, twelve are start-ups, with a market share of approximately 7 percent in 2019.[10] However, start-ups—especially if they haven't started production yet—will find that market conditions become increasingly unfavorable to them as a result of their cost structures. In particular, high fixed costs at low volumes burden these companies, so any start-up that cannot scale up quickly will disappear. By contrast, international OEMs will aim to capture additional market share, since they must extend their penetration of the BEV market to adhere to regulations, such as dual-credit policies.

E-powertrain technology will standardize. The observed technological variance in batteries, power electronics, E/E, and e-drives is expected to decline. The market will converge on just a few standardized designs, as happened with ICE powertrain designs. This presents a significant opportunity for suppliers that can deliver integrated platform solutions for the powertrain, especially if they have a competitive capex base through synergies and economies of scale.

Native BEV platforms will gain higher shares. The benchmark shows that Chinese OEMs have realized short time to market by using shared or modified ICE platforms. However, as noted earlier, we expect more OEMs to develop dedicated BEV platforms to satisfy demand—a trend that will reduce time to market while also conveying design and cost advantages. Moreover, it is expected that BEVs will increasingly be produced on dedicated production lines instead of (at present) flexible, shared ICE/BEV production lines.

Non-Chinese OEMs will need to leverage their assets, such as an exciting brand image, superior engineering expertise, and state-of-the-art production facilities, to differentiate themselves from their Chinese competitors. Simultaneously, they must simplify their portfolios to offer fewer but highly targeted and locally adapted options, supported by

International OEMs will aim to capture additional market share, since they must extend their penetration of the BEV market to adhere to regulations.

[10] Number of start-ups and their market share were derived from calculations using production data for electric vehicles from IHS Markit, Light Vehicle Powertrain Production Forecast, April 2020. Please note that while the production data are from IHS Markit, the classification into start-up and incumbent, as well as the calculation of the start-ups' market share, were developed by McKinsey and are neither associated with nor endorsed by IHS Markit.

Exhibit 13

Our insights give an idea about potential actions for players to drive winning battery-electric-vehicle design in China.

	International	Local
OEMs	Adapt a **customer-centric-design** philosophy and prioritize features and functions valued most by customers	Intensify **design-to-cost practices** to unlock potential cost savings
	Leverage assets—eg, brands, state-of-the-art production, and superior engineering; innovate using **design-to-cost** concept rigorously	Leverage **knowledge of consumer preferences** to differentiate offerings and to expand into **new revenue models**
	Reduce portfolio and adopt agile product development to **shorten time-to-market**	Solidify **brand image** to differentiate products from existing and new competition
	Expand into **new revenue models**—eg, software updates and maintenance	Further enhance **customer experience**
Suppliers	**Partner** with Chinese OEMs to advance engineering maturity and to help maximize cost savings	Select **long-term strategy** and develop **integrated solutions** for key modules
	Strive for **innovation leadership** in highly valued fields, potentially through strategic partnerships	**Broaden OEM customer** base and experiment with innovative business models

Source: McKinsey analysis

additional revenue streams through software and other technologies. In contrast, Chinese OEMs should continue to increase their profitability by focusing on cost savings while increasing their revenues through more differentiated offerings. Sophisticated pricing strategies and new revenue streams will be important.

For suppliers, partnerships will be crucial. Non-Chinese suppliers could leverage their engineering maturity to become leaders in innovation. Chinese suppliers might broaden their customer base by helping non-Chinese OEMs to gain a foothold in the market (Exhibit 13).

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McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales

McKinsey's recent analysis of global electric-vehicle markets shows both challenges and opportunities ahead.

July 2020

This article was written collaboratively by members of McKinsey's Automotive and Assembly Practice: Thomas Gersdorf, Patrick Hertzke, Patrick Schaufuss, and Stephanie Schenk.

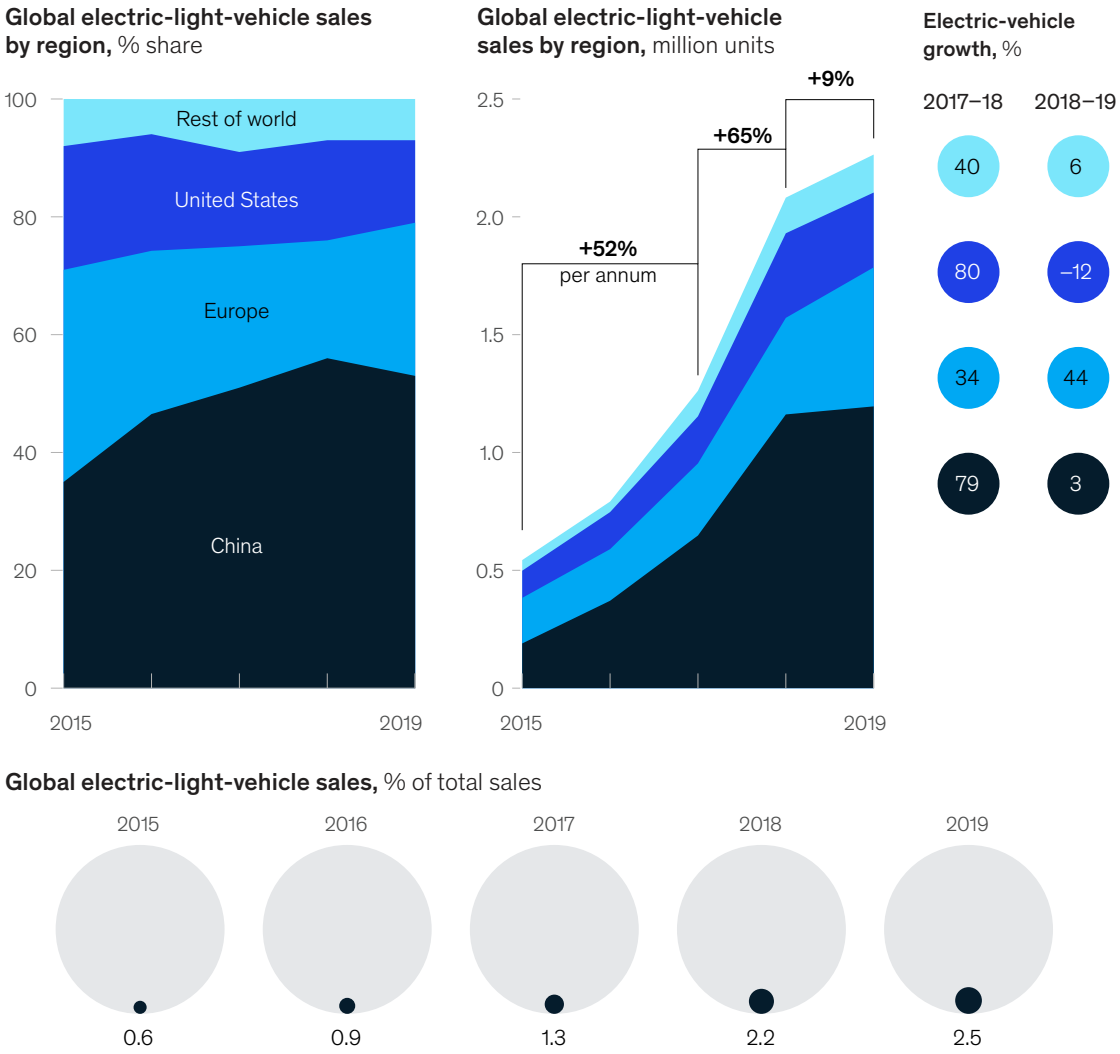
McKinsey's proprietary Electric Vehicle Index (EVI) assesses the dynamics of the e-mobility market in 15 key countries worldwide (for more information on the metrics evaluated, see sidebar "What is the Electric Vehicle Index?"). EVI results for 2019 and the first quarter of 2020 provide important insights about market growth, regional demand patterns, market share for major electric-vehicle (EV) manufacturers, and supply-chain trends.

Growth in the electric-vehicle market has slowed

EV sales rose 65 percent from 2017 to 2018 (Exhibit 1). But in 2019, the number of units sold increased only to 2.3 million, from 2.1 million, for year-on-year growth of just 9 percent. Equally sobering, EV sales declined by 25 percent during the first quarter of 2020. The days of rapid expansion have ceased—or at least paused temporarily. Overall, Europe has seen the strongest growth in EVs.

Exhibit 1

In contrast to a slowdown of EV sales globally in 2019 and in the first quarter of 2020, Europe expanded its market share to 26 percent, growing by 44 percent.



Source: Ev-volumes.com; Light Vehicle Sales Forecast, May 2020, IHS Markit

What is the Electric Vehicle Index?

McKinsey's proprietary Electric Vehicle Index (EVI) focuses on battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Since we created the EVI, several years ago, it has given organizations in the automotive, mobility, and energy sectors a detailed view of the electric-vehicle (EV) market, while highlighting potential future trends.

The EVI explores two important dimensions of electric mobility:

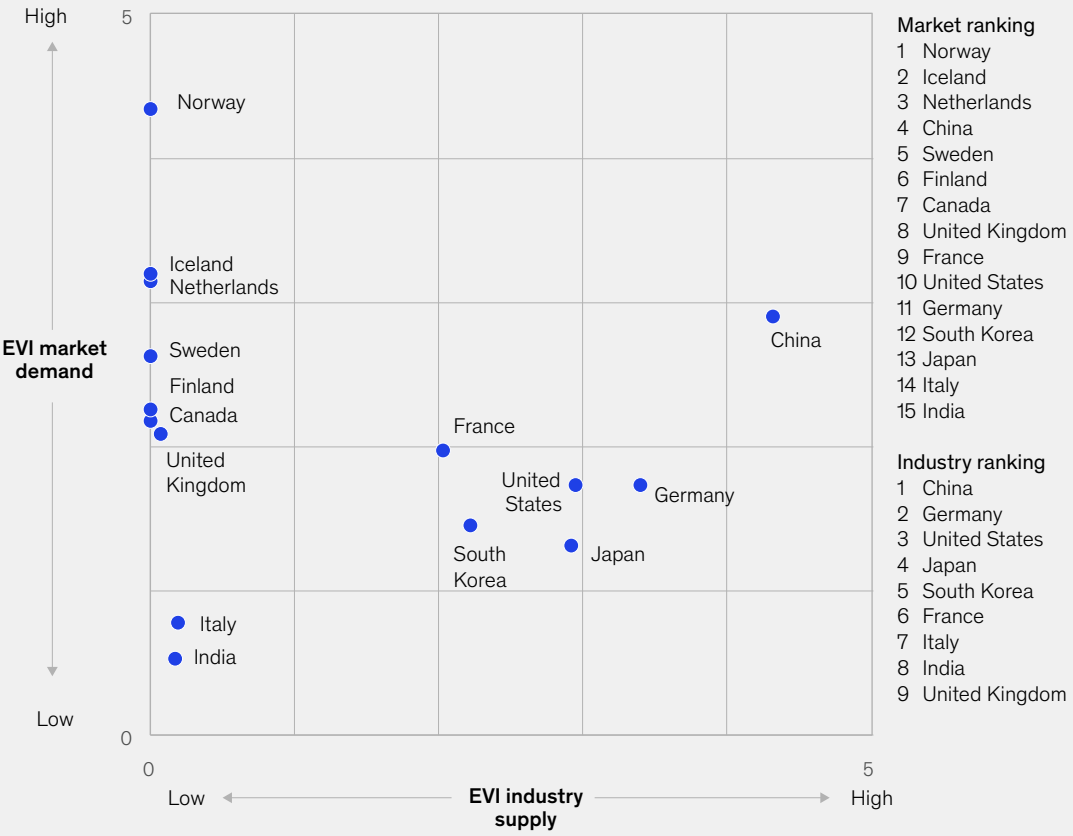
1. *Market demand* analyzes the share of EVs in the overall market, as well as factors affecting EV penetration in each country, such as incentives (for instance, subsidies), existing infrastructure, and the range of available EVs.
2. *Industry supply* explores the share of a country's OEMs in the production of EVs and EV components, such as e-motors and batteries, looking at both current and projected numbers.

The EVI assesses the key performance indicators in each country and rates them on a scale from 0 to 5 for every dimension. These scores serve as the basis for the final country ranking (exhibit).

Exhibit

The Electric Vehicle Index for 2020 shows that Nordic countries lead for market demand, while China and Germany dominate industry supply.

Overall Electric Vehicle Index (EVI) results, score (range from low of 0 to high of 5)



Source: McKinsey Center for Future Mobility

Although these developments are disappointing, they largely reflect the decline of the overall light-vehicle market, which fell by 5 percent in 2019 and by an additional 29 percent in first-quarter 2020. Despite the overall drop in sales, global EV market penetration increased by 0.3 percentage points from 2018 to 2019, for a total share of 2.5 percent. With additional growth in the first quarter of 2020, EV penetration is now at 2.8 percent.

To gain different perspectives on the EV industry's growth and other topics, we interviewed various McKinsey experts (see sidebar, "Expert views on the electric-vehicle sector's future development"). The remainder of this section explores regional market variations.

Expert views on the electric-vehicle sector's future development

How will the global electric-vehicle (EV) market develop over the short to mid term? Many uncertainties persist, so we asked some McKinsey experts about their views on pressing issues.

China's declining EV sales, resulting from the government's subsidy cuts, raise concerns about the sustainability of customer demand in the country. How will sales develop, especially considering the COVID-19 crisis, and what is the government's strategy to achieve its 25 percent sales target for new-energy vehicles (NEVs) by 2025?

Ting Wu (partner, Shenzhen): NEVs are still a top priority for the Chinese government and take center stage in its post-coronavirus stimulus plan. The government recently decided to extend NEV subsidies by two years, to the end of 2022. In addition, RMB 10 billion ($1.4 billion) will be invested to expand the charging network for electric vehicles (EVs) this year. Overall, increased government purchases will probably drive the market. Nevertheless, achieving the 25 percent target by 2025 will be a challenge and probably require additional policy instruments and new business models to spur sufficient consumer demand.

Automakers are relying on EVs to achieve Europe's upcoming carbon-dioxide emissions limits for 2020 and 2021. Although we have seen strong dynamics across countries, will the industry sell enough EVs to avoid looming penalty payments, and what might be the impact of the COVID-19 crisis?

Patrick Schaufuss (associate partner, Munich): OEMs have invested more than €30 billion in EVs over the past two years to meet Europe's upcoming carbon-dioxide regulations. OEMs plan to make a spot landing on the targets. Every gram these companies miss costs the industry about €1.5 billion, but overachieving would tighten their 2030 targets.

In the first quarter of 2020, we saw increased momentum on the consumer side for buying EVs, despite the COVID-19 pandemic. Other signs also suggest that the momentum of EVs will be sustained in Europe—for instance, the creation of additional purchase incentives, the timely creation of EV standard operating procedures, and an infrastructure rollout.

Given the recent loosening of the US federal emissions regulations, how will the trajectory of the US market and the EV strategies of traditional automakers evolve over the coming years?

Russel Hensley (partner, Detroit): Vehicle electrification strategies will remain relatively consistent, despite the uncertainty about current regulations and the ensuing debate between federal and state policy makers. While some automakers may have cut or delayed their EV programs, domestic OEMs must continue their efforts to enhance the average fuel economy of their new fleets, given the large share of light trucks, SUVs, and compact utility vehicles.

Many automakers use plug-in hybrid electric vehicles (PHEVs) as a bridge to a fully electric future. How will this technology develop?

Ruth Heuss (senior partner, Berlin): Over the past few years, sales of plug-in hybrid electric vehicles have been growing more slowly than sales of pure battery electric vehicles (BEVs). PHEVs represented less than a third of the global EV market in 2019. While most automakers offer them, the number of available models will remain less than half of the number of BEV models over the coming years. Although a higher driving range is one of the major advantages of PHEVs, the electric range of BEVs has

been constantly increasing: it rose by 55 percent from 2017 to 2020 and is now around 400 km. Given typical driving behavior, PHEVs recently started to face regulatory headwinds as their environmental impact raised concerns. In reaction, some countries have reduced or entirely abolished monetary subsidies for PHEVs, further increasing their already higher price point for consumers. In 2019, among the key EV markets, PHEVs dominated EV sales in only three countries: Finland, Iceland, and Sweden. We therefore currently forecast that PHEVs will represent only 5 to 10 percent of the global market by 2030. That could fall even further as emissions regulations are increasingly based on real consumption.

We hear very little about hydrogen–fuel-cell EVs, except for a few models from Japanese and South Korean manufacturers. Will the technology contribute to green mobility in the future, and if so, will it emerge first in the passenger or light commercial-vehicle segment?

Anna Orthofer (associate partner, Vienna): There is actually quite some noise around hydrogen on the commercial-vehicle front. Most large OEMs have teamed up to work on the technology—for example, Daimler and Volvo, Toyota and Traton, and Honda and Isuzu. New players, such as Nikola and Hyzon, are entering the market, and Chinese companies are moving fast. The big suppliers are following by building a comprehensive system offering in fuel cells.

Overall, we see fewer and fewer OEMs that do not think about hydrogen as a necessary part of their powertrain portfolios. In light of carbon-dioxide regulation for trucks (such as the European Union's "–30 percent by 2030" target), each ton in weight and each kilometer in range will improve total costs of ownership for fuel cells relative to batteries. For long-haul trucks, our models show that fuel-cell electric vehicles can break even with battery electric vehicles within the next five years. They will also achieve lower total costs of ownership than diesel before 2030.

Markets such as China, Sweden, and the United Kingdom have reacted strongly to EV-incentive changes. Yet customer demand—independent of government subsidies—remains a major concern in the industry. Who is currently buying EVs, and what is required to scale up the market?

Timo Möller (partner, Cologne): Early adopters of BEVs appear to constitute a specific segment of consumers, best described as tech-savvy urban people with above-average incomes and a familiarity with online shopping. Beyond first movers, consideration of EVs has significantly increased among consumers over the past few years as they have come to recognize the numerous benefits of EVs. To scale up the market, OEMs should thus systematically try to affirm the consumers' growing positive attitudes about many aspects of EVs, such as the driving experience and subsidies. OEMs should also disprove consumer fears, such as range anxiety, that do not reflect reality and solve pressing pragmatic problems, such as the availability of charging stations.

Shifting portfolios from internal-combustion engines (ICEs) to EVs is a major challenge for traditional automakers, especially considering profitability. What is the current view of profits for EVs sold today? Will falling costs and rising consumer demand overcome the need for government support, and how can OEMs share the pain?

Patrick Hertzke (partner, London): Shifting the vehicle portfolio from ICE to PHEV/BEV—a change driven by regulation and shifting consumer demand—is now a paramount focus for traditional automakers. Many of them are concerned about profitability. The majority of EV models are still unprofitable, but this is changing. At-scale EV producers will have a clear cost advantage in the near term, while other OEMs are more likely to seek partnerships to co-develop EV platforms or even fully merge. EV growth across transport sectors also remains one of the most critical levers in global efforts to reduce carbon-dioxide emissions and improve urban air quality. EV supply chains will get even greener over time with the expansion of renewables and the recycling and reuse of batteries. COVID-19 and the related economic crisis will raise the stakes further as the world seeks cleaner transport solutions but could require governments to continue their subsidies and penalties as well. They may also need to add other measures, such as green early-scrappage programs, which encourage consumers to swap older cars for EVs.

Inspired by the ambitious EV strategies of automakers, battery-cell suppliers are ramping up their capacities. What are the key trends and challenges for the battery supply chain?

Markus Wilthaner (associate partner, Vienna): The uptake of EVs has supercharged industrialization and expansion in the industry. Battery-cell makers have an outsize growth opportunity in front of them. By revenue, they could become some of the largest automotive suppliers globally. This opportunity comes with huge challenges and trade-offs. They need to ramp up production capacities fast, while remaining disciplined about capital expenditures. Battery-cell makers must also stabilize production processes and achieve very high yields, while constantly pursuing product innovations. Every

year, they must reduce costs to deliver on long-term contracts and remain competitive, while simultaneously seeking new business models and opportunities for differentiation. Finally these suppliers must solve challenges related to sustainability by turning the whole battery value chain, from mining to recycling, into a sustainable and responsible industry.

Demand for battery cells is expected to increase at least fourfold over the next five years, and cell chemistry is moving to nickel-rich cathodes. What are the developments and challenges on the battery raw-materials side?

Ken Hoffman (expert, New Jersey): There are three main challenges for the battery raw-materials supply stream. First, will the industry produce the quality of the nickel, lithium, and cobalt necessary? Second, will it produce the extremely specific quality needed? Third, can this production meet the ever more stringent environmental, social, and governance requirements imposed by regulators?

What will enable a truly sustainable form of electric mobility in the future? Where does the industry stand on sourcing raw materials sustainably, green electricity, and battery recycling? Is awareness of these challenges increasing?

Hauke Engel (partner, Frankfurt): The journey to truly sustainable electric mobility has only begun. The industry has made great progress increasing the number of available hybrid and fully electric-vehicle models, and costs keep coming down. Now the industry must work hard to drive down the cost of batteries and to achieve end-to-end sustainability—from truly sustainable raw-materials supplies (such as zero-carbon steel) to circular-economy principles in vehicle design. I'm excited to see OEMs increasingly starting to recognize and embrace these challenges. The scale and complexity of the problems may seem daunting, and solving them will require imagination, determination, and new forms of collaboration. Failure is not an option. We must simultaneously solve the climate challenge and secure the prosperity of our automotive industries and the people they employ.

EV market trends vary by region

Key EV markets suggest shifting regional dynamics, with China and the United States losing ground to Europe. EV sales remained constant in China in 2019, at around 1.2 million units sold (a 3 percent increase from the previous year). In the United States, EV sales dropped by 12 percent in 2019, with only 320,000 units sold. Meanwhile, sales in Europe rose by 44 percent, to reach 590,000 units. These trends continued in first-quarter 2020 as EV sales decreased from the previous quarter by 57 percent in China and by 33 percent in the United States. In contrast, Europe's EV market increased by 25 percent.

China

The relatively slow 2019 growth of China's EV market reflects both an overall decline in the light-vehicle market and significant cuts in EV subsidies. The central government, for example, eliminated purchase subsidies for vehicles that achieve electric ranges (e-ranges) of less than 200 kilometers and reduced subsidies by 67 percent for battery electric vehicles (BEVs) with e-ranges above 400 kilometers. These cutbacks reflect the government's strategy of scaling back monetary incentives for new-energy vehicles (NEVs) and transitioning to nonmonetary forms of support. Since 2019, OEMs have received credits for each NEV produced. The credits take into consideration factors such as the type of vehicle, as well as its maximum speed, energy consumption, weight, and range. Regulators base credit targets for each OEM on its total production of passenger cars. If a manufacturer does not reach the target, it must purchase credits from competitors that have a surplus or pay financial penalties.

In first-quarter 2020, China was heavily affected by the COVID-19 pandemic. EV sales dropped by 57 percent from the fourth quarter of 2019 as consumer demand declined sharply. Several EV manufacturers were also forced to halt production. In response, the central government extended through 2022 (though at reduced rates) monetary incentives that were about to expire. The government also prolonged the purchase-

Key EV markets suggest shifting regional dynamics, with China and the United States losing ground to Europe.

tax exemptions of NEVs through 2022. These measures, together with the government's recent decision to invest billions of renminbi in the charging infrastructure as part of an economic-stimulus program, could help EV sales rebound in 2020.

The United States

EV sales rose by 80 percent in the United States in 2018, driven by the market launch of the standard version of the Tesla Model 3. The increase slowed in 2019 because of several developments. With Tesla's overseas deliveries increasing and the gradual phaseout of the federal tax credit in January and July 2019, the brand's US sales for that year declined 7 percent, or 12,400 units. Meanwhile, the Chevrolet Volt was phased out, and its sales fell by 14,000 units. Sales of the Honda Clarity also decreased by 8,000 units.

Some international OEMs did successfully launch new models in the United States in 2019, including Audi (the e-tron) and Hyundai (the Kona). Sales of VW's e-Golf also increased. These three brands accounted for more than 24,500 units of EV sales, but their strong performance could not offset the decline of other models. US sales of EVs decreased further in first-quarter 2020, by 33 percent from the previous quarter.

The federal government's recent moves to loosen regulations could further decelerate the EV market in the United States. In March 2020, for instance, the government revised fuel-economy standards, to a 2026 target of 40 miles per gallon (mpg), from 54 mpg. Today's low oil prices are also contributing to the EV slowdown, since they significantly lower the total cost of ownership for vehicles powered by internal-combustion engines (as compared with EVs). These changes are creating great uncertainty, and the US EV market's development could depend largely on the number of states adopting California's Zero-Emission Vehicle Program and on the vicissitudes of oil prices.

Europe

Unlike other key EV markets, Europe has seen significant EV growth. In 2019, sales increased by 44 percent, the highest rate since 2016. The European Union's new emissions standard—95 grams of carbon dioxide per kilometer for passenger cars—could also boost EV sales because it stipulates that 95 percent of the fleet must meet this standard in 2020 and 100 percent in 2021. BEV sales picked up speed substantially, with a 70 percent growth rate propelled by three models: the Tesla Model 3, Hyundai Kona, and Audi e-tron.

EV sales increased by double-digit percentages in 2019 in almost every European country. Sales in some smaller markets, such as Estonia, Iceland, and Slovakia, declined in absolute terms. EV sales in Germany and the Netherlands contributed nearly half—44 percent—of overall EV-market growth in Europe; in both countries, units sold increased by about 40,000 units. Those numbers translate into a 2018 growth rate of 55 percent for Germany and 144 percent for the Netherlands. In both countries, these strong EV sales resulted from increased demand for new models, the availability of existing models with larger battery sizes, and changed government incentives (for more information on the power of incentives, see sidebar "Purchase subsidies juice EV sales.")

Purchase subsidies juice EV sales

As recent developments in China and Europe show, government subsidies remain a major driver of electric-vehicle (EV) sales. In 2019, several countries changed these incentive schemes in ways that show how sensitive customers are to price adjustments. For instance, the EV market in China declined by 31 percent in the second half of the year after the government cut subsidies. In the United Kingdom, sales of plug-in hybrid electric vehicles (PHEVs) fell by 15 percent after the government stopped subsidies for hybrids. Government subsidies also play an important role in increasing growth. When Germany reduced the company-car tax in January 2019, it promoted a surge in EV sales later that year. Similarly, the strong 2019 showing of the EV market in the Netherlands occurred partly because consumers wanted to purchase vehicles before the benefit-in-kind tax rate increased in 2020.

As first-quarter 2020 figures show, the EV markets in several European countries could accelerate this year because of recently increased incentives:

- France revised its bonus–malus (reward–penalty) scheme, based on carbon-dioxide emissions. Companies must meet new requirements to receive the environmental bonus for low-emitting vehicles and face a drastic increase in the environmental penalty for high-emitting ones.
- Germany extended tax incentives for electric company cars through the end of 2030. It has also increased purchase-price subsidies for EVs and will continue them until the end of 2021.
- Sweden implemented a bonus–malus system in 2018. A January 2020 amendment for test procedures to determine the carbon-dioxide emissions of vehicles will benefit PHEVs.

While government subsidies obviously have a strong influence on the development of the EV market, future growth may depend largely on the extent to which the COVID-19 pandemic hits EV markets in the short term.

In the first quarter of 2020, European EV sales rose as the overall EV penetration rate increased to 7.5 percent. With the exception of Hong Kong, all of the top ten markets for EV penetration were in Europe (Exhibit 2). The strong regulatory tailwinds and high purchase incentives in several European countries could dampen the impact of the COVID-19 pandemic and further boost the EV market. That said, EV sales will probably face tougher impediments in second-quarter 2020, when the pandemic's impact on Europe's countries and economies should peak. So far, no European OEM has changed its plans to roll out EV models, and several countries are discussing additional purchase incentives as part of their economic-stimulus programs.

Electric-vehicle makers are debuting new models and boosting sales of existing ones

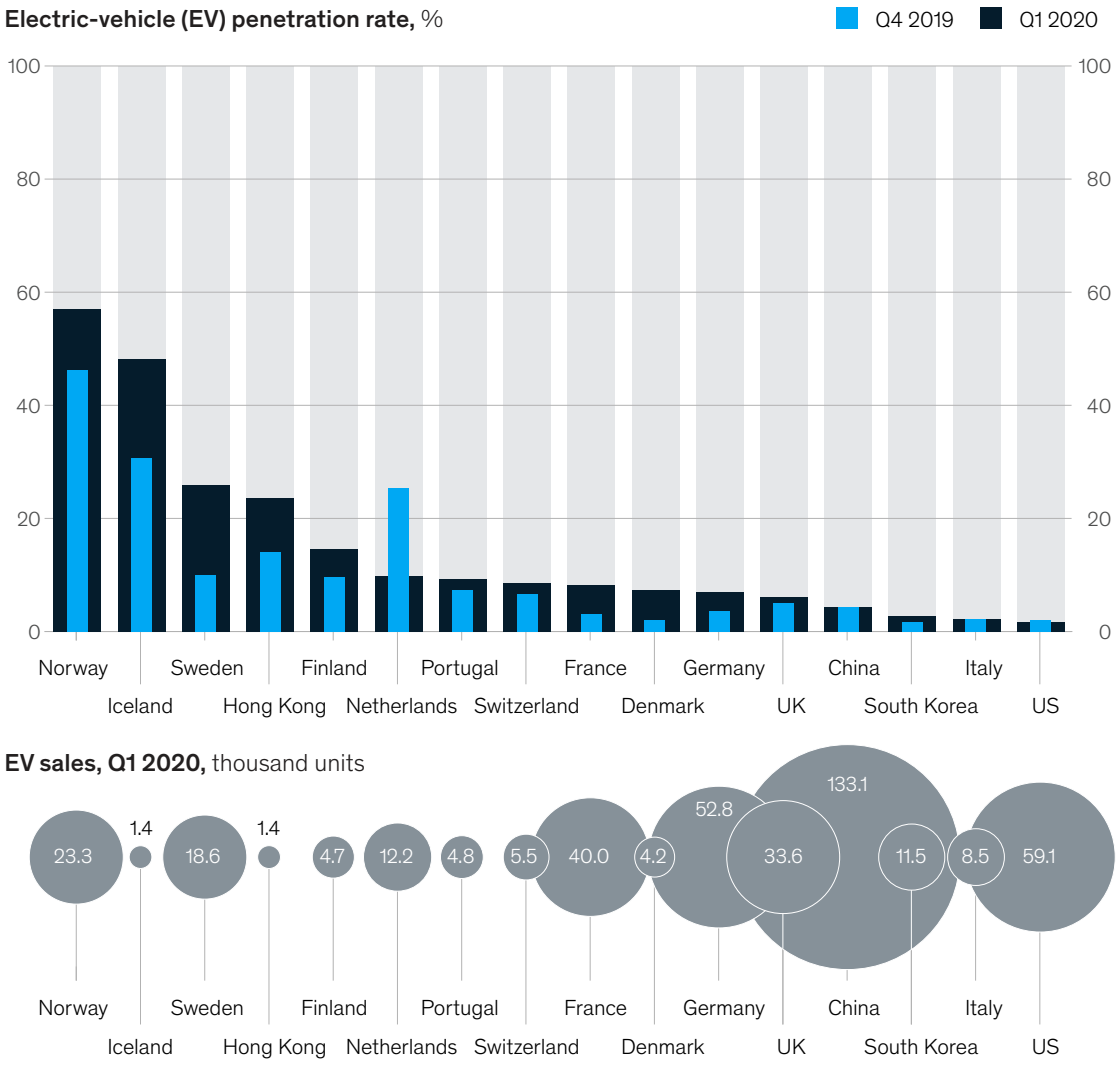
Automakers launched 143 new electric vehicles—105 BEVs and 38 plug-in hybrid electric vehicles (PHEVs)—in 2019. They plan to introduce around 450 additional models by 2022 (Exhibit 3). Most are midsize or large vehicles. Given the estimated production levels, German manufacturers, with an expected volume of 856,000 EVs, could overtake Chinese players in 2020. That would boost Germany's global production share from 18 percent in 2019 to 27 percent in 2020.

New emissions regulations in Europe and China, which will come into force between 2020 and 2021, partly explain why EV-model launches have increased significantly. These regulations pose major challenges for automakers, since they will face potential penalties of up to several billion euros unless they increase their EV penetration rates significantly.

Among EV manufacturers, Tesla continued as market leader in 2019, with 370,000 units sold globally, for a market share of about 16 percent, up from 12 percent in 2018 (Exhibit 4). The launch of the Model 3 outside of the United States was the main reason for this surge. With 300,000 units

Exhibit 2

Nine of the top ten markets for electric-vehicle penetration rate were European.



Source: Ev-volume.com; Light Vehicle Sales Forecast, May 2020, IHS Markit

sold worldwide, the Model 3 outpaced sales of the BJEV EU-series threefold and sales of Nissan Leaf fourfold.

At the brand level, most Chinese EV manufacturers faced declining sales, while demand was high for the EV offerings of some international OEMs.

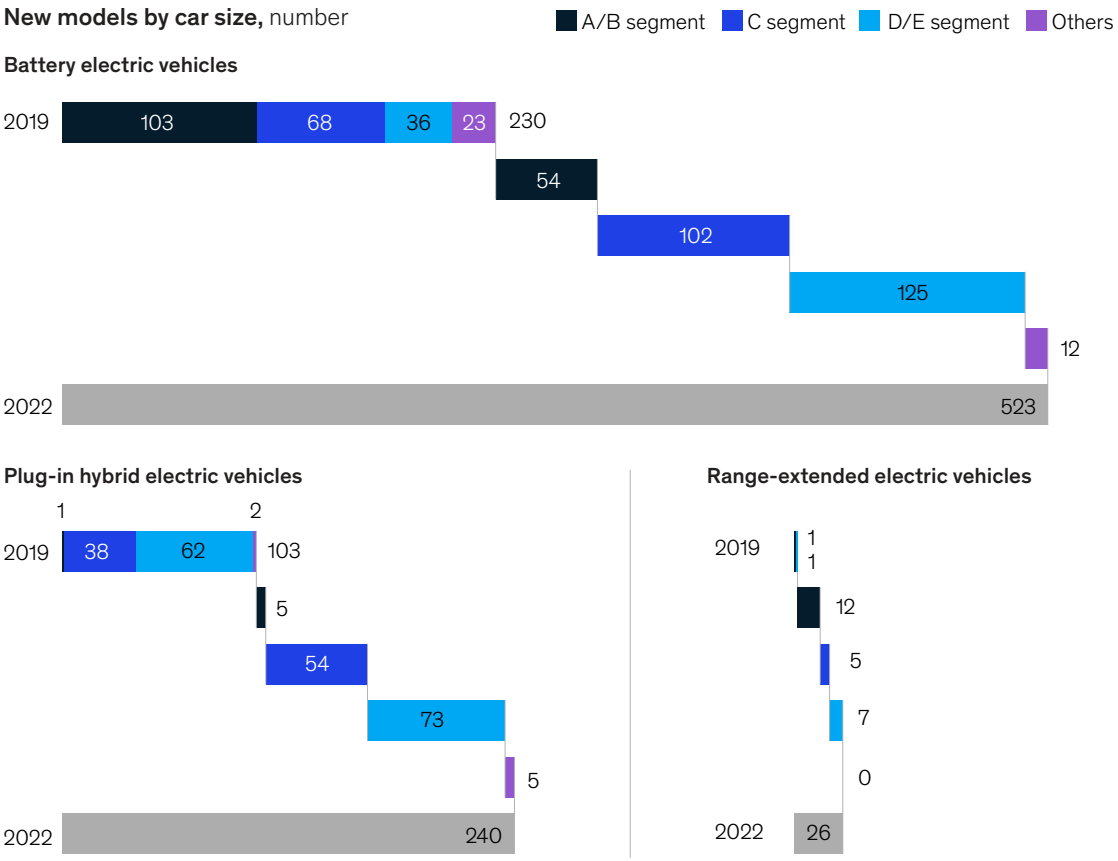
The supply chain is localizing

With announced launches of new EV models spiking, both automakers and suppliers are increasing their global footprints in target markets by localizing the production of vehicles and components. For example, Tesla began construction of its Shanghai plant in January 2019 and delivered the first locally produced EV that December. The company plans to build its next production plant in Germany by 2021. Similarly, Volkswagen and Toyota have announced plans to set up EV plants in China.

In a similar development, battery-cell manufacturers are increasing their production capacities in target markets. The total lithium-ion–battery market

Exhibit 3

About 450 new electric-vehicle models will be launched through 2022.



Source: IHS Light Vehicle Powertrain Forecast, May 2020

for EV passenger cars grew by 17 percent, to 117 gigawatt-hours in 2019, enough to power 2.4 million standard BEVs. Most of the new capacity will be established in Central Europe, with companies preparing to meet demand throughout the region. Company announcements suggest that the global market should expand to about 1,000 gigawatt-hours by 2025. The Chinese battery maker CATL had the largest market share in 2019, at 28 percent, while its absolute capacity grew by 39 percent. CATL has recently continued its global expansion, signing new contracts with several international OEMs and setting up a factory in Germany.

South Korean manufacturers are trying to catch up with large-scale investments in new overseas production plants. SK Innovation, for example, announced it would invest an additional €5 billion in its planned US factory, while LG Chem is investing $2.3 billion in a joint venture (JV) with General Motors in the United States.

Overall, JVs are becoming a popular collaboration model in the battery industry, with an increasing number of partnerships announced in 2019. This trend mainly reflects the fact that JVs enable automakers to lock in enough capacity to reach their ambitious sales and production targets. Automakers also prefer multisourcing strategies involving a number of cell makers. Even Tesla, which used to rely solely on cells from Panasonic, signed new contracts with CATL and LG Chem for the Chinese market in 2019.

Cybersecurity in automotive

Mastering the challenge

March 2020

by Ondrej Burkacky, Johannes Deichmann, Benjamin Klein, Klaus Pototzky, and Gundbert Scherf

Introduction and key insights

The four ACES disruptions – autonomous driving, connected cars, electric vehicles, and shared mobility – have dominated the agenda of automotive industry leaders in recent years. These innovations, built on the digitization of in-car systems, the extension of car IT systems into the back end, and the propagation of software, turn modern cars into information clearinghouses. Hacking of connected cars by security researchers has made headlines over the past few years, and concerns about the cybersecurity of modern vehicles have become real. Lately, regulators have also started working on defining the minimum cybersecurity requirements for new cars. The UNECE WP.29[1] regulation on cybersecurity and software updates is on the horizon and will trigger a paradigm shift in the automotive industry in the UNECE member countries. Other countries like the US and China have issued best practices and frameworks but no regulations yet. Given the influence of UNECE, however, a broad adoption of its regulation across the world is expected.

With these first regulatory programs for cybersecurity and software updates in the automotive sector, the regulator will require automotive OEMs – the responsible parties for vehicle homologation – to demonstrate adequate cyber-risk management practices throughout development, production, and postproduction of their vehicles, including the ability to fix software security issues after the sale of vehicles and over the air.

In this context and based on our extensive research and analyses, we offer a perspective on three key questions for the automotive industry:

— What are the specific trends and drivers of cybersecurity in the automotive industry and why is this a paradigm shift for the industry?

— How are these drivers going to affect the automotive industry's long-established value chains?

— How can players inside and outside the industry prepare and position themselves for the upcoming market developments and anticipated segment growth?

While the following paragraphs provide a summary of our research, the remainder of the report will address these questions in detail.

Engine power, fuel consumption, driving comfort, and the precision of a car's chassis and body are just a few dimensions that define the quality of a car. With more and more core vehicle functions enabled by software running on specialized hardware chips, the security of those components – cybersecurity – will become yet another dimension of quality in the automotive industry, in much the same way that physical safety is a major concern and quality parameter today.

This measure of quality is underpinned by regulatory activities that impose minimum standards for managing cybersecurity risks and require OEMs to have the ability to fix security issues via software updates. Cybersecurity will become nonnegotiable for the industry.

In order to excel at cybersecurity, new processes, skills, and working practices along the automotive value chain will be required. This includes identifying cyber risks, designing secure software and hardware architectures, and developing and testing secure code and chips, ensuring that issues can be fixed – even years later – via software updates.

The rising need for cybersecurity will trigger investments over the next few years. We expect to see the market grow from USD 4.9 billion in 2020 to USD 9.7 billion in 2030, with software business representing half of the market by 2030. The strong growth of the market will create many new business opportunities for suppliers, established IT firms, specialist niche firms, start-ups, and many others, especially in the software development and services market. At the same time, the dynamics of the growing market will also challenge today's leaders in the market.

[1] UNECE, Proposal for a new UN Regulation on uniform provisions concerning the approval of vehicles with regard to cyber security and of their cybersecurity management systems; UNECE, Proposal for a new UN Regulation on uniform provisions concerning the approval of vehicles with regard to software update processes and of software update management systems.

1. Cybersecurity is becoming a new dimension of quality for automobiles

Software is one of the key innovations in modern vehicles

Software and electrical/electronic (E/E) components are and will continue to be among the key innovations in modern vehicles. The market is expected to grow from USD 238 billion in 2020 to USD 469 billion in 2030, corresponding to an annual growth of over 7 percent per year.[2]

This growth is driven to a large extent by software, which is becoming a key differentiator. Software is driving innovation in the four ACES categories:

— **Autonomous.** Autonomous cars, which have been the subject of fantasy for a long time, are becoming reality. Leading companies have already driven millions of miles on public roads with them, but so far always under the watchful eye of a human behind the steering wheel. The disengagement rate in field tests, i.e., how often the human driver needs to take over control, is rapidly declining, putting fully autonomous cars in reach within mere years. While the autonomous car offers great advantages, it comes with the risk of hackers interfering with steering or breaking. Such incidents would foster fear of autonomous cars and put the whole technology at risk.

— **Connected.** Cars are becoming more and more connected. The services enabled by connectivity today range from sending destination addresses to the vehicle, to receiving real-time traffic information, to parking the vehicle remotely via a smartphone app. However, the connectivity of cars is a potential attack vector for hackers to compromise a full fleet of cars, which is the worst nightmare of every OEM.

— **Electric.** The rise of electric cars started several years ago and they are gaining more and more traction as their range increases and their price decreases. Challenged by many start-ups, almost all incumbent OEMs have embarked on the journey to including electric cars in their product portfolios. The electric car per se is not more susceptible to sabotage than a conventional car, but attacks on charging infrastructure can have severe effects, from power outages to fires.

— **Shared.** Enabled by connectivity, new business models for transportation have become viable, such as car sharing and ride hailing. The trend in mobility is moving away from car ownership and towards shared-car solutions, which is significantly increasing vehicle utilization. This trend requires full protection of user data – a breach of sensitive data could foster massive distrust of the business model.

A deeper look into the connected car shows three types of software that will drive innovation in this area:

— In-vehicle services: All software within the vehicle that runs on electronic control units (ECUs) or domain control units (DCUs) within the car

— OEM back-end services: Cloud services for both the vehicle and user

— Infrastructure and third-party services: Software links between the vehicle and infrastructure, e.g., gas/charging, parking, insurance.

While the industry is investing in innovations across these types of software to enhance the customer experience and increase the value of modern cars, manufacturers must also build in cybersecurity from the beginning to avoid creating cyberattack-prone digital platforms and vehicles.

With every line of code, the cyber risk to modern vehicles increases, and security researchers have demonstrated its impact and cost

Over the last several years, modern cars have become data centers on wheels. Comparing the lines of code in modern connected cars with aircrafts and PCs provides a glimpse into the challenges of securing these vehicles. Today's cars have up to 150 ECUs and about 100 million lines of code; by 2030, many observers expect them to have roughly 300 million lines of software code. To put this into perspective, a passenger aircraft has an estimated 15 million lines of code, a modern fighter jet about 25 million, and a mass-market PC operating system close to 40 million.[3] This abundance of complex software code is a result of both the legacy of designing electronic systems in specific ways for the past 35 years and the growing requirements and increasing complexity of systems in connected and autonomous cars. This amount of code creates ample opportunity for cyberattacks – not only on the car itself but also on all components of its ecosystem (e.g., back end, infrastructure).

The cyber risk of connected cars has become clear over the past few years, as security researchers have revealed various technical vulnerabilities. In these scenarios, the "attackers" were not exploiting the vulnerabilities with bad intentions but rather

[2] Source: McKinsey, "Mapping the automotive software-and-electronics landscape through 2030," July 2019.
[3] Source: McKinsey, "The race for cybersecurity: Protecting the connected car in the era of new regulation," October 2019.

disclosing information to OEMs to help them fix those issues before malicious attackers caused actual harm. Some of the recently reported vulnerabilities are listed in Exhibit 1.

After becoming aware of the vulnerabilities, OEMs fixed the issues and provided software updates. But, depending on the affected car model, its E/E architecture, and the OEM's ability to provide software updates over the air, some software updates required visits to dealerships, resulting in much higher costs for carmakers.

Cybersecurity will be nonnegotiable for securing market access and type approval in the future

Unlike in other industries, such as financial services, energy, and telecommunications, cybersecurity has so far remained unregulated in the automotive sector – but this is changing now with the upcoming UNECE WP.29 regulations on cybersecurity and software updates.[4] Under this framework, OEMs in UNECE member countries (see Exhibit 2) will need to show evidence of sufficient cyber-risk management practices end to end, i.e., from vehicle development through production all the way to postproduction. This includes the demonstrated ability to deploy over-the-air software-security fixes even after the sale of the vehicle. Other countries like China and the US have so far not issued similar regulations, only guidelines and best practices. We expect the new UNECE regulation to become a de facto standard even beyond its members.

Looking at today's passenger car market volumes in only the ten largest countries regulated under UNECE WP.29, the new regulations will likely affect over 20 million vehicles sold worldwide. This does not even include commercial vehicles, or any other type of motor vehicle regulated under UNECE WP.29.

Exhibit 1

Software vulnerabilities have been observed across the entire digital car ecosystem

In-vehicle services

2018: Researchers demonstrated **>10 vulnerabilities in various car models,** gaining local and remote access to infotainment, telematics, and CAN buses

2018: Researchers exploited vulnerabilities of some **infotainment systems** and gained control of microphones, speakers, and navigation systems

2015: Researchers remotely sent commands to the **CAN bus of a specific car** that had an OBD2 dongle installed to control the car's windshield wipers and breaks

OEM back-end services

2019: Malware infected the **back end,** making laptops installed in police cars unusable

2019: Vehicle data exposed during registration allowed for remote denial-of-service attacks on cars

2015: Researchers demonstrated vulnerabilities within the back end, **gaining access to door control**

Infrastructure/third-party services

2018: EV home chargers could be **controlled** by accessing the home Wi-Fi network

2018: Security issues discovered in 13 **car-sharing apps**

2017: Rental car companies **exposed personal data**

Enterprise technology

2019: Memory vulnerability at a cloud provider **exposed data incl. passwords, API keys, and tokens**

2019: Hack of an OEM's **automotive cloud** via third-party services and tier-1 supplier network

2018: Cloud servers hacked and **used for cryptomining**

Production and maintenance systems

2019: A malware infection caused significant production disruption at a car parts manufacturer

2018: An ex-employee breached the company network and downloaded large volumes of **personal information**

2017: Ransomware caused the **stop of production** across several plants

Source: Press search

[4] UNECE, Proposal for a new UN Regulation on uniform provisions concerning the approval of vehicles with regard to cyber security and of their cybersecurity management systems; UNECE, Proposal for a new UN Regulation on uniform provisions concerning the approval of vehicles with regard to software update processes and of software update management systems.

What is UNECE's role in regulating automotive cybersecurity?

The World Forum for Harmonization of Vehicle Regulations (WP.29) is a worldwide regulatory forum within the institutional framework of the UN Economic Commission for Europe (UNECE). It establishes regulatory instruments concerning motor vehicles and motor vehicle equipment in over 60 markets globally, based on three UN agreements adopted in 1958, 1997, and 1998.

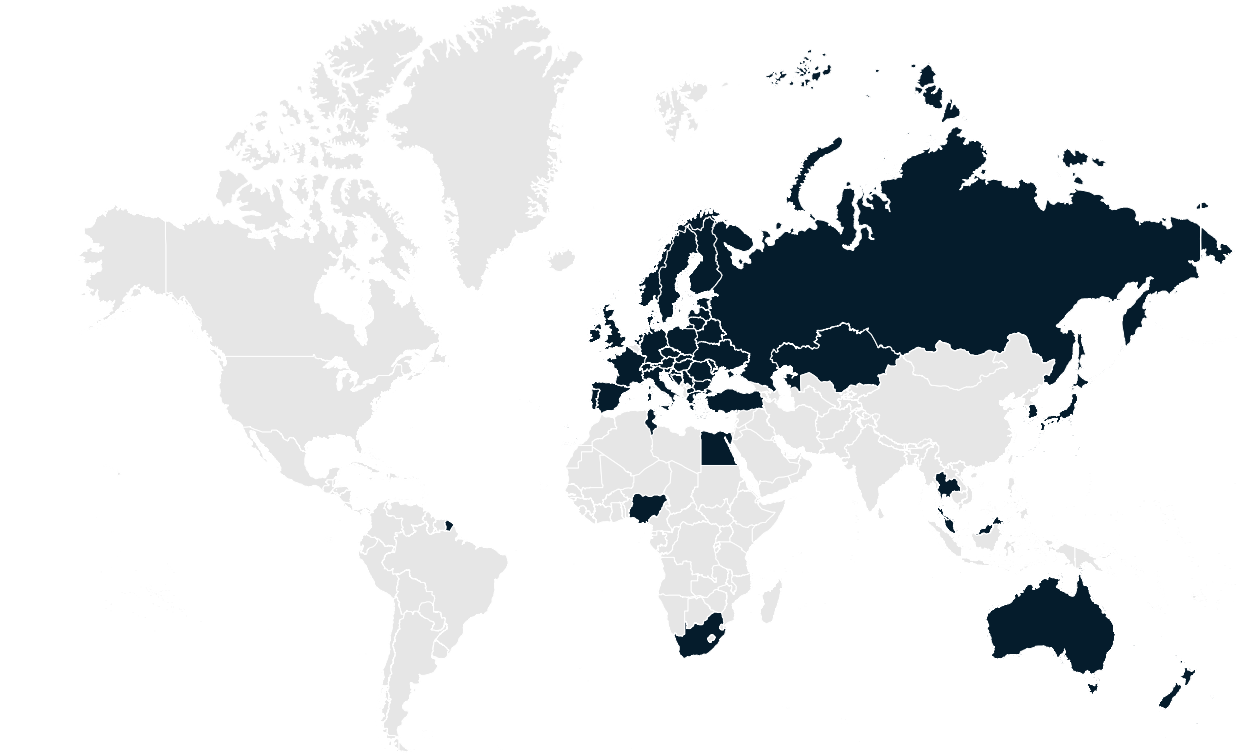
At the time of writing this report, UNECE is drafting a proposal for two new UN regulations. The first regulation is on uniform provisions concerning the approval of vehicles with regard to cybersecurity and cybersecurity management systems. The second regulation is on vehicle software update processes and software update management systems. For ease of readability, we'll refer to both regulations as the UNECE WP.29 regulations on cybersecurity and software updates throughout this report.

Once this proposal is accepted by UNECE and the regulations are adopted by its member countries, OEMs will be required to implement specific cybersecurity and software-update practices and capabilities for vehicle type approvals – effectively rendering cybersecurity a nonnegotiable component of future vehicles.

Exhibit 2

Cars in over 60 countries will be affected under the new World Forum for Harmonization of Vehicle Regulations framework on cybersecurity and software updates

World Forum for Harmonization of Vehicle Regulations (WP.29) under the UN Economic Commission for Europe (UNECE)



1 "Agreement concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations" (original version adopted in Geneva on March 20, 1958)

Source: UNECE ECE/TRANS/WP.29/343/Rev.27 – Status of the Agreement, of the annexed Regulations and of the amendments thereto – Revision 27

2. The automotive industry is rethinking cybersecurity along the entire value chain

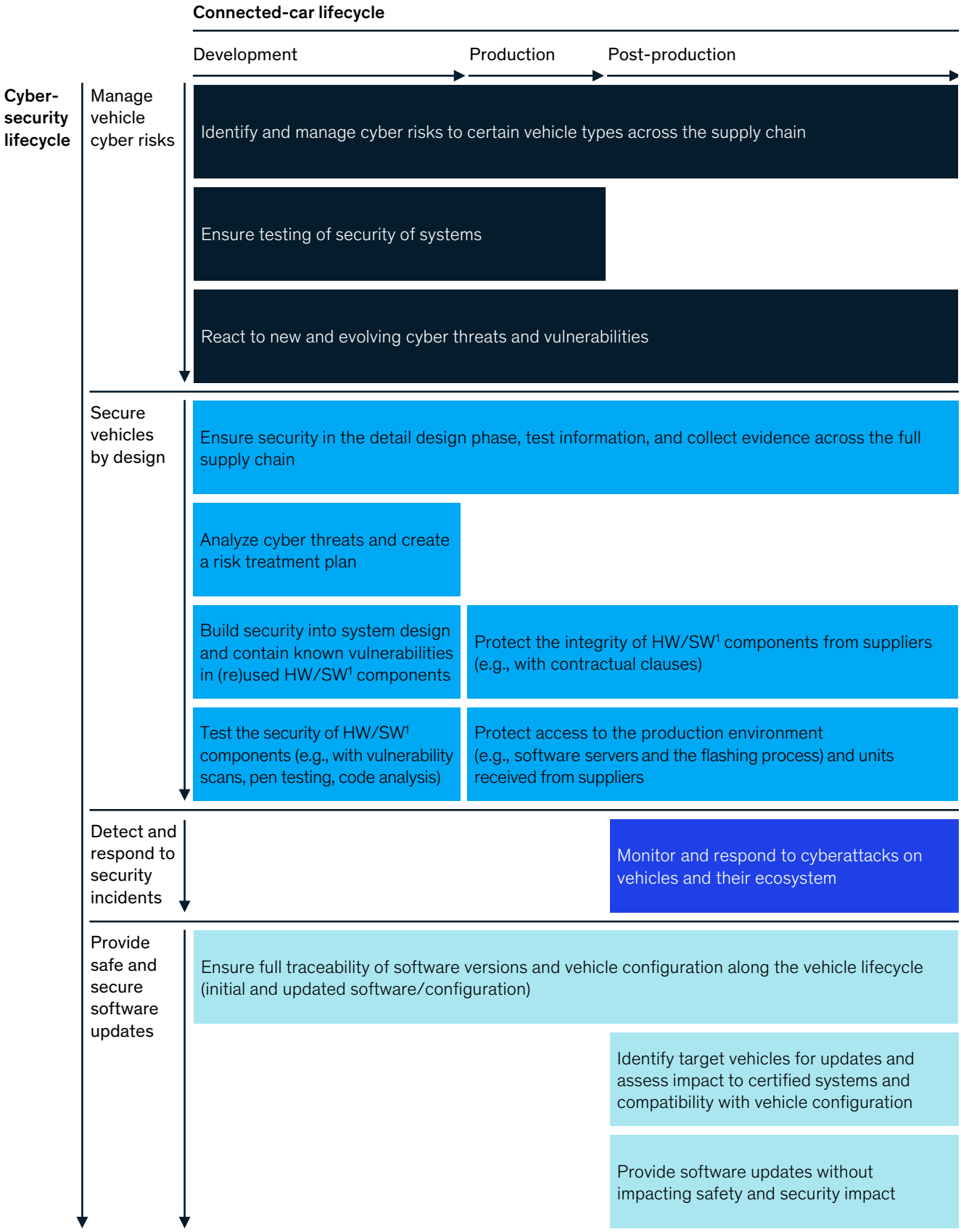
Getting cybersecurity right requires efforts from multiple parties along the value chain, for the entire digital lifecycle of modern vehicles

Ultimately, OEMs are responsible for the homologation of their vehicles and demonstrating their adherence to regulations and mandatory legal requirements. However, since OEMs source a large share of their vehicle components from suppliers and semiconductor manufacturers, their upstream value chain partners will also be required to follow and implement state-of-the-art practices to mitigate cybersecurity risks and produce vehicles that are secure by design. These partners must provide evidence of adhering to the regulations to support the type-approval process, which is the responsibility of the OEM. Looking at the current drafts of the UNECE WP.29 regulations on cybersecurity and software updates, it becomes evident that the value chain is affected across four areas (see Exhibit 3):

- **Cyber-risk management.** Automotive players must ensure end-to-end cyber-risk management and identify relevant cyber risks in their vehicle types (and in adjacent ecosystem components that might impact vehicle safety or security) and ensure that they implement measures to mitigate such risks. This includes reacting to evolving threats.
- **Security by design.** OEMs must develop secure vehicles from step one by adopting state-of-the-art practices in hardware and software engineering, and ensuring that vehicle types (and adjacent ecosystem components that might impact vehicle safety or security) are designed, built, and tested for security issues and any cyber risks are mitigated properly. Although OEMs are ultimately responsible for cybersecurity, all participants in the value chain need to contribute.
- **Detection and response.** Vehicle manufacturers must be able to detect technical vulnerabilities and security issues (e.g., cyberattacks) in their vehicles and adjacent ecosystem components (e.g., the back end or third-party services) that might impact vehicle safety or security.
- **Safe and secure updates.** Automotive players must be able to respond to any detected security event and provide software updates to fix security issues. To do so, they must systematically identify target vehicles for updates and ensure that software updates will not harm certified safety-relevant systems and are compatible with the vehicles' configuration.

The UNECE regulation is broken down into 4 concrete areas of cybersecurity and spans across the entire vehicle lifecycle

SIMPLIFIED



1 Hardware/software

Source: UNECE WP.29, "Draft Recommendation on Software Updates of the Task Force on Cyber security and Over-the-air issues," ISO/SAE 21434:2018 committee draft; McKinsey

While certain practices are already in place today, the upcoming regulations, higher levels of enforcement, and potential liability implications will require a much more explicit agreement between parties along the automotive value chain on what exactly is expected of each other. To adhere to this higher level of rigor, we are expecting automotive players to:

— Define clear roles and responsibilities for vehicle cybersecurity (not just enterprise cybersecurity) and establish interfaces and points of contact for vehicle cybersecurity between players

— Agree on a minimum set of cyber-risk management and cybersecurity practices in contractual agreements and derive measurable service levels similar to what has been good practice in other dimensions of vehicle quality (e.g., safety)

— Clarify organizational, technical, and legal (e.g., IP) prerequisites that allow security testing and attestation of vehicle software security of the entire E/E vehicle architecture or down to the individual ECU.

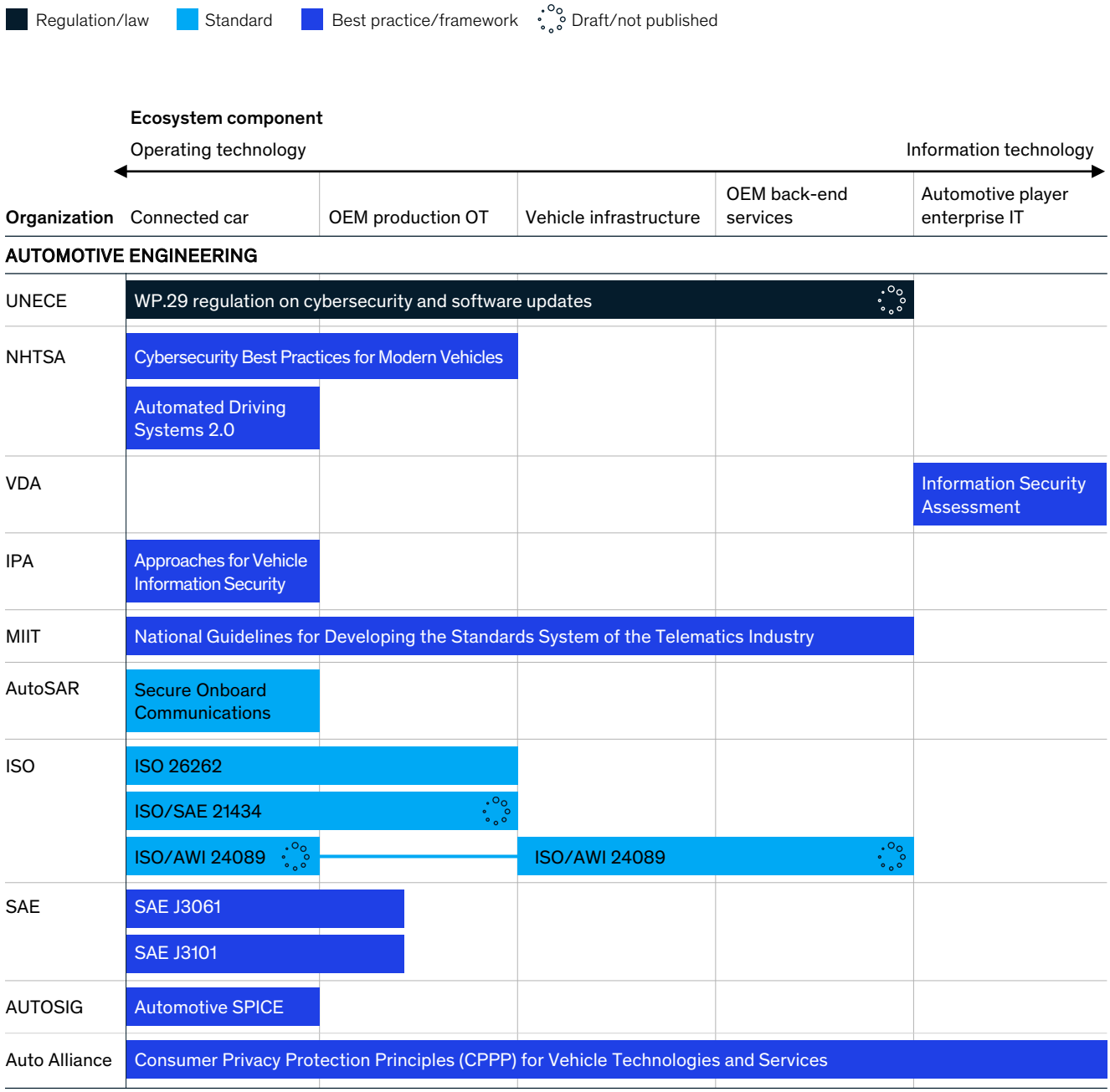
However, security does not stop at the production of vehicles – it is important throughout the entire vehicle lifecycle, as security vulnerabilities can be discovered at any given time. It will require OEMs and suppliers to continually detect and react to security issues until vehicles have reached their end of life, just as we expect aircraft or engine manufacturers to continuously monitor their aircrafts and engines to detect and fix any operational, safety, or security issues for as long as that equipment is in use by any owner.

New standards will raise the bar for vehicle cybersecurity and allow for independent attestation of an automotive company's security practices

Currently, only narrow standards and guidelines exist for specific technical procedures for securing hardware and software in vehicles, e.g., standards for hardware encryption or secure communication of ECUs (see Exhibit 4). While the UNECE WP.29 regulations on cybersecurity and software updates set an organizational framework and minimum requirements that impact all automotive players along the value chain, they do not provide any detailed guidance on operational practices. However, the new ISO/SAE 21434 standard, "Road vehicles – cybersecurity engineering," (still a working draft) is seen by industry experts as the first standard that lays out clear organizational, procedural, and technical requirements throughout the vehicle lifecycle, from development to production to after-sales. In parallel, the ISO/

Exhibit 4 (1/2)

Unlike in other industries, cybersecurity has remained unregulated in the automotive industry beyond general IT regulations

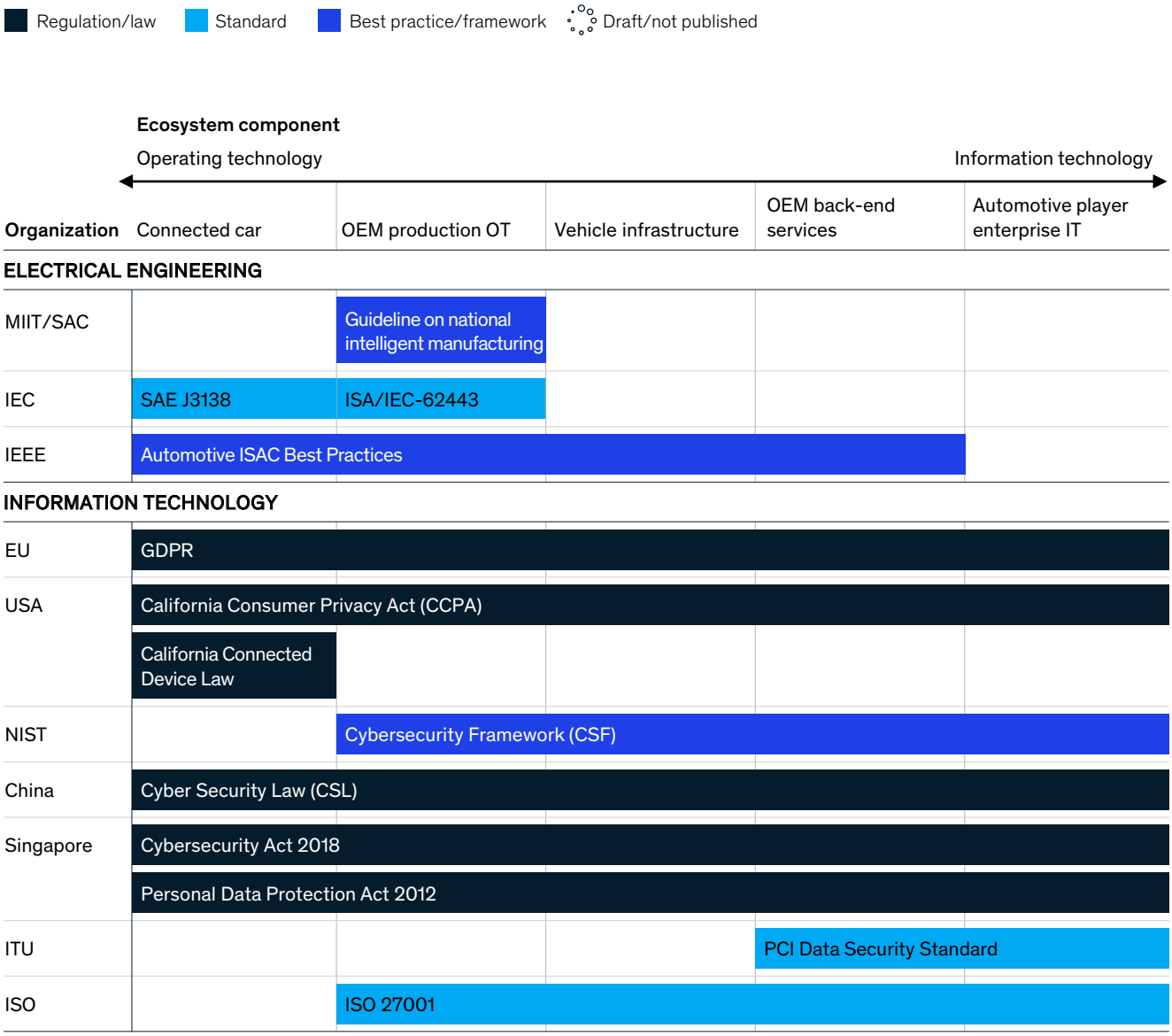


AWI 24089 standard, "Road vehicles – software update engineering," is also currently under development. Although it is not dedicated to cybersecurity, we expect it to contain cybersecurity-related content. A first draft is expected by mid-2020 and some more time will be needed to finalize it.

These standards will allow the industry to implement common cybersecurity practices specific to vehicle development and manufacturing. They will also allow an assessment of adherence to those practices and attestation by third parties, which can be used between industry players to demonstrate adherence to the standards, for example, in contracts between OEMs and suppliers. The independent attestation of security practices will create a growing market for auditing, inspection, and certification companies (see Section 4). Legal experts also see this as the foundation for solving legal disputes and liability issues in case of cybersecurity-related vehicle incidents.

Exhibit 4 (2/2)

Unlike in other industries, cybersecurity has remained unregulated in the automotive industry beyond general IT regulations



Securing hardware and software in modern vehicles will require new skills and talent for a true security-by-design approach

Other industries have already developed best practices for secure software development, including leading tech companies, aerospace and defense companies, and critical infrastructure companies. OEMs and all other automotive players can lean on these best practices and combine them with the upcoming standards for the automotive industry to develop the new capabilities required throughout the full development cycle – not only for hardware and software development (see Exhibit 5).

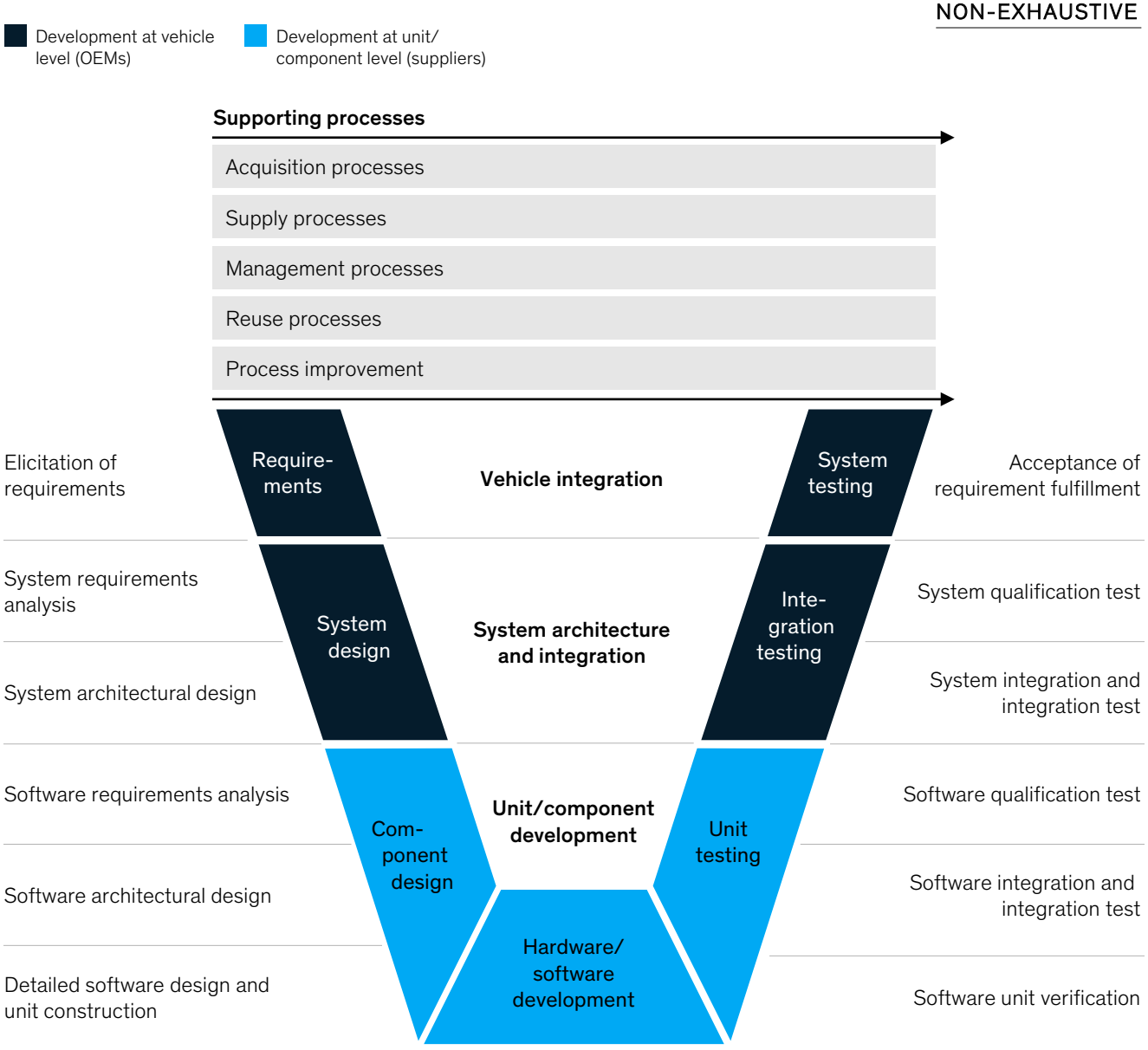
- Requirements: Define requirements such that cybersecurity is built into the system design and the security of hardware and software is tested.
- System design: Define requirements for confidentiality, integrity, and availability of data, and design systems in accordance to these requirements.
- Component design: Analyze the security requirements for software components and design them accordingly.
- Hardware/software development: Implement the security requirements into the hardware and software.

Exhibit 5

OEMs and suppliers will need to integrate cybersecurity measures throughout development – new talent and skills required

ILLUSTRATIVE

NON-EXHAUSTIVE



Source: McKinsey analysis, Automotive SPICE (A-SPICE®) framework

— Unit testing: Test the correct implementation of security requirements using software unit verification, software integration tests, and software qualification tests.

— Integration testing: Perform system integration and system qualification tests to ensure the correct implementation of the cybersecurity requirements.

— System testing: Perform acceptance testing of requirement fulfillment on the basis of a criteria catalog (e.g., derived from UNECE).

New capabilities and cybersecurity requirements along the development cycle will require significant reskilling and upskilling of the current workforce in many cases. The raising of skill requirements is also reflected in the market (see Section 4), where we see a variety of new products and services that all require new skills.

But even beyond the activities mentioned above, many other areas require upskilling. For example:

— The procurement of security components requires a more collaborative approach compared to the procurement of mechanical parts, e.g., chassis, powertrains, or batteries, where exact specifications can be detailed up front. Although specifications for security components can be laid out in the design phase, adjustments can be expected during the full development cycle. Due to the high complexity of cybersecurity, evaluating providers, especially for capabilities, will become much more challenging compared to sourcing physical parts or normal software.

— Project management must take security-by-design seriously and account for relevant cybersecurity-related activities and artefacts being part of the project, e.g., prioritizing cybersecurity in the product backlog.

— Dealerships, as the front line to automotive customers, will need to speak to cybersecurity matters (e.g., when reports of vulnerable cars or recent attacks are in the news) and must be able to assist in cybersecurity-related maintenance activities such as deploying software updates when over-the-air updates are not available.

— Customer communication teams will need to convey and communicate cybersecurity-related matters, like addressing public fears of cars being vulnerable to cyberattacks or navigating the challenging task of upholding external communication in case of a cybersecurity incident.

In the aviation industry, for example, some players have already built up new skills to address their cybersecurity needs. One leading aviation and defense company developed all of the above-mentioned skills internally. It has also built up SOCs to monitor its enterprise IT as well as its OT production. Going further, it's even offering these services to the market, strengthening its position and credibility on the cybersecurity front.

3. Managing cyber risk throughout the vehicle lifecycle will require new working practices

Stricter cyber-risk management processes and compliance documentation

Stricter cyber-risk management processes and compliance documentation will need to be established. This includes management systems (cybersecurity management systems), and software update management systems, roles and responsibilities, and formal processes to assess and manage cyber risks for vehicles. Players should either adapt their existing management systems (e.g., quality management) or establish new systems, depending on their organizational structures and maturity.

So far, the role of vehicle cybersecurity (or product cybersecurity) has not yet been established by all OEMs in a way that fully reflects its multifaceted character at the intersection of quality, engineering, IT, software, procurement, and legal. The responsibility for cybersecurity is rather oftentimes assigned to functional domain owners, with basic functionality being provided by the OS and middleware. For enterprise IT, the role of a chief information and security officer overseeing the entire IT landscape is well established; a similar role is needed for vehicle cybersecurity. This can be achieved by either redefining the current information and security officer role or completely building a new cross-functional role.

Regulators, type-approval authorities, insurers, and business partners will likely demand more formal structures and processes, including diligent documenting. They will likely also require evidence of both the operational effectiveness of cybersecurity practices and OEM compliance with relevant regulatory requirements and standards (e.g., the UNECE WP.29 regulations or the ISO/SAE 21434 and ISO/AWI 24089 standards) in the future.

New ways of working and service levels between automotive value chain players ensure "security by design" for vehicles

As cybersecurity becomes relevant for type approval, OEMs will require their upstream partners, such as suppliers and semiconductor companies, to adhere to higher industry standards and follow new procedures. This will necessitate new contractual agreements. Adhering to regulatory requirements for process documentation will likely result in new forms of assessments, audits, and certifications; for example, independent third-party auditing of suppliers against emerging standards, such as ISO/SAE 21434 and ISO/AWI 24089. From a market perspective, this will likely create demand for implementation support as well as assessment and attestation services with respect to cybersecurity and software-update practices and their respective industry standards.

Ability to detect security incidents in the digital car ecosystem beyond the classical enterprise perimeter

OEMs will have to respond to security incidents as they occur. These incidents could take the form of everything from evidence of a new or potential vulnerability to even an actual attack on their vehicles. Automotive players will need new organizational, procedural, and technical capabilities to detect and respond to cybersecurity events in and around their vehicles:

- **Organizational capabilities** to embed cybersecurity in the DNA of the organization and establish practices to deal with cybersecurity topics in a diligent way.
- **Procedural capabilities** to monitor vehicles and the adjacent ecosystem components for security events based on the collection and analysis of log event data by a vehicle SOC and to respond to security events that cannot be resolved by typical tier-one and tier-two analysts inside the vehicle SOC.
- **Technical capabilities** for software inside vehicles and the digital car ecosystem that collects log events and feeds the vehicle SOC and security incident response team with information to detect anomalies and other adverse events (e.g., a vehicle intrusion detection system). Additionally, capacities for investigating root causes of anomalies need to be built up.

Furthermore, the blueprints of potential attacks will likely be sold by criminals to other criminals on the dark web. With this in mind, automotive players should also embrace the power and knowledge of global cybersecurity communities of white-hat hackers and security researchers and follow other industries in establishing bug bounty programs. Incentive and reward programs to encourage friendly hackers to report vulnerabilities they discover should be implemented to allow automotive players to fix issues before they are widely known and exploited with malicious intent.

As vehicles manufactured in one part of the world get sold in other parts, data privacy and privacy regulations must be accounted for. This leads to the potential requirement of region-specific versions of both software and vehicle SOCs.

The setup of vehicle SOCs and organizational anchoring is an open topic with no clear best

practices as of now. For in-house vehicle SOCs, there are at least three options for anchoring the unit: (1) integrate it into the enterprise IT or OT SOC, (2) integrate it into the quality assurance unit, or (3) integrate it into the vehicle software R&D unit. Beyond these options, outsourcing the entire vehicle SOC either to an enterprise SOC service company or a dedicated vehicle SOC company is also an option. Lastly, there is also the option of creating a joint vehicle SOC service between multiple parties, increasing collective defense against cyber threats by sharing insights from recent attacks and joining forces to fight against potential future ones.

Time will tell which of these options will become the dominant setup. Initially, we believe that vehicle SOCs will be established internally to build up competencies and experiment with different models. Either way, we expect a growing market for vehicle SOC services over the next few years (see Section 4).

Service levels for providing security patches throughout the vehicle lifecycle

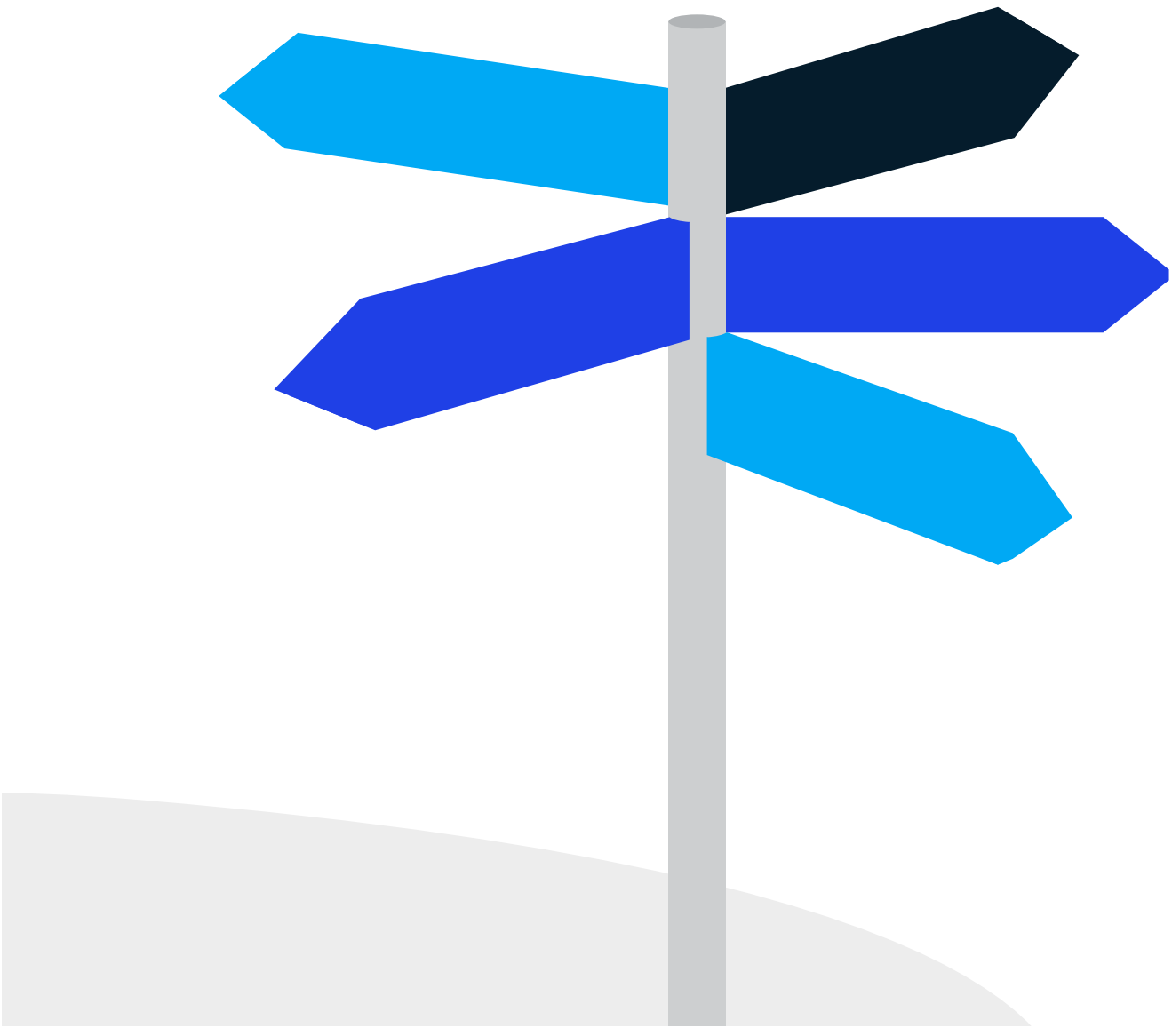
Providing security patches throughout the full vehicle lifecycle is essential for safe vehicle operation. Vehicles are often driven for ten years or even longer, requiring regular updates over a very long period. This makes vehicles more akin to aircrafts or vessels, which see software updates provided over longer periods, contrary to updates for consumer products like PCs, smartphones, tablets, or smart appliances.

The industry will need to adapt to a long-life vehicle operating system and solid software architecture to master complexity and be able to provide new software releases and updates over many years. This means, for example, that the contractual relationship between OEMs and suppliers must clarify who is providing which software updates over which period. Work on the ISO/AWI 24089 standard, which will address software update management, has recently started and will provide guidance on update requirements.

Examples from the PC and smartphone business show that security updates are essential for safe device operation. Today, for example, the initial release of Windows XP is unsecure and infected within minutes after establishing an internet connection.[5] For cars, security updates are even more important since attacks could put the lives of drivers, passengers, and others at risk. In addition to the human cost, the price point of a vehicle is much higher than that of a smartphone, so consumer expectations of software patches throughout a vehicle's lifetime will likely be high.

[5] SANS Internet Storm Center, survival time. Retrieved from https://isc.sans.edu/survivaltime.html on March 9, 2020

4. Automotive executives should prepare their cybersecurity strategy



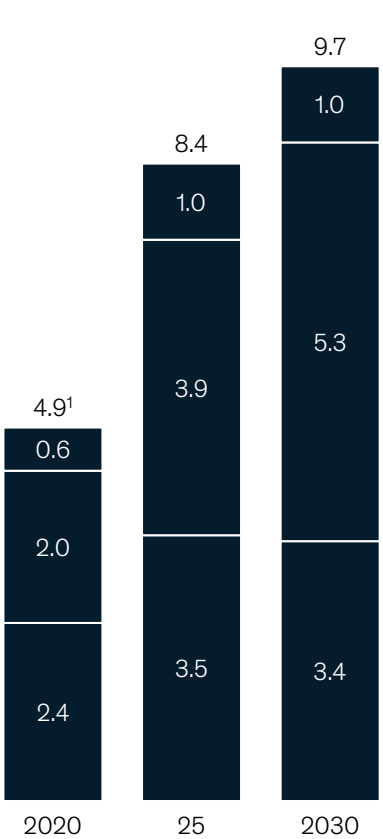
Perspectives on market size and opportunities for automotive cybersecurity

We have broken down the automotive cybersecurity market into three elements: cybersecurity hardware, cybersecurity-related software development efforts, and cybersecurity processes and solutions. Based on external expert interviews, McKinsey analysis, and predictive modeling of the automotive software market, we have created a market forecast for automotive cybersecurity until 2030. We expect the market to grow from USD 4.9 billion in 2020 to USD 9.7 billion in 2030, corresponding to annual growth of over 7 percent (see Exhibit 6). This is in line with the growth of the total market for automotive software and hardware. We expect to see a significant amount of change, in these areas in particular:

- **OEMs** are pursuing vertical integration, e.g., by building their own cybersecurity components or **even** software stacks.
- **Suppliers** are pushing their way up and down the value chain, e.g., by offering specialized cybersecurity consulting services.
- **Start-ups** are entering the market with innovative solutions, e.g., specialized threat detection applications or vehicle SOCs as a service.
- **IT and OT companies** are expanding into the adjacent automotive cybersecurity market, e.g., by offering back-end solutions or cybersecurity components.
- **Semiconductor companies** are pushing their way up the value chain, e.g., by providing software that's optimized for their chips.

Exhibit 6

The cybersecurity market will grow significantly for automotive in the coming years



Submarket	CAGR 2020-30	
Total	7%	
Cybersecurity hardware components	6%	Dedicated security components for encryption and key storage (eHSM and TPM)
Cybersecurity-related software development efforts	10%	Implementation of cybersecurity components (e.g., encryption functionality) and requirements in functional domains Integration and testing of cybersecurity components and additional effort due to cybersecurity requirements in functional domains
Cybersecurity processes and solutions	4%	Efforts to implement new regulatory requirements Software traceability (inventory and compatibility management, and impact assessment) Risk management and incident response Vehicle monitoring using SOCs

1 Sum does not add up due to rounding

Source: Analysis based on data from "Automotive software and electronics 2030 – mapping the sector's future landscape," McKinsey, 2019

Cybersecurity hardware components

There are currently two types of dedicated security components for security algorithms and key storage:

- Embedded hardware security module (eHSM): offers basic functionality
- Trusted Platform Module (TPM): provides more power and flexibility than an eHSM.

These hardware modules are already integrated into some ECUs. We expect an increasing penetration of these modules until 2024, when every ECU will have either an eHSM or a TPM. The choice between the two is determined by an ECU's required performance and flexibility. We note that the additional software requirements for security also lead to slightly higher needs for computing power and memory. This effect is excluded from our model since it increases the market for general chips, but has no effect on dedicated security elements.

The hardware security market is expected to grow until 2025 and then remain flat until 2030. This is driven by three predictions:

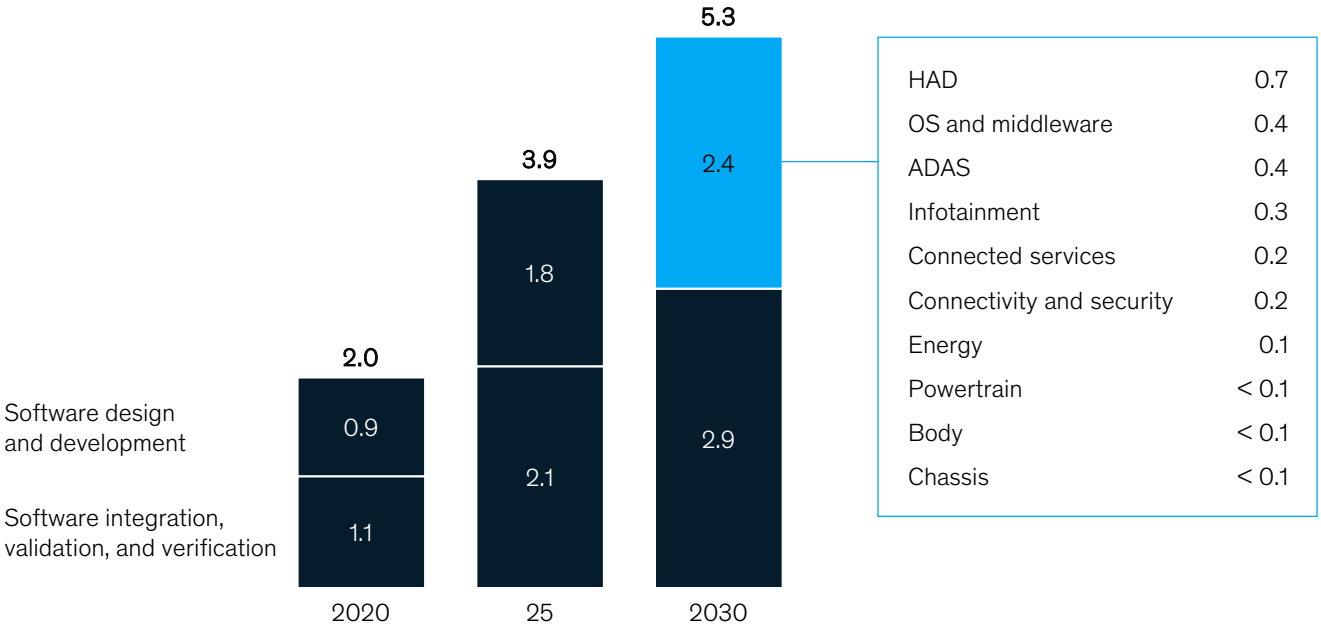
- **Higher ECU sales.** The total number of ECU sales will increase until 2025 and then remain flat afterwards. Increasing connectivity and software features will lead to an increase in the number of ECUs per car, while the consolidation of ECUs within the car balances the increase in the number of ECUs.
- **Security-module market saturation.** The penetration rate of hardware security modules will also reach saturation around 2025, corresponding to the expectation that the UNECE WP.29 regulations on cybersecurity and software updates will be enforced in 2024.
- **Modest increases in hardware prices.** The cost of security hardware is not expected to increase significantly. Higher performance and new features are expected to compensate price declines due to high volumes and optimized production.

We expect the market to stay in the hands of the incumbent semiconductor companies, but there are also opportunities for OEMs or suppliers to enter the market if hardware security modules become an important differentiating factor. Similar behavior has already been observed in other markets; for example, a leading automotive OEM has developed its own specialized chips for autonomous driving. In the consumer space, a few OEMs have developed their own system-on-chip – some systems-on-chips even include dedicated security components.

Exhibit 7

The software development market is expected to reach USD 5.3 bn by 2030, driven by ADAS/HAD but also OS and middleware

Cybersecurity-related software development effort market size
USD billions



Source: Analysis based on data from "Automotive software and electronics 2030 – Mapping the sector's future landscape," McKinsey, 2019.

Cybersecurity-related software development
Software is the second key element for making cars secure. We describe our perspective on this aspect of the automotive cybersecurity market with two categories in mind:

— **Software design and development.** Market players must specify requirements and design components and develop the actual software for cybersecurity components as well as functional components for meeting security requirements.

— **Software integration, validation, and verification.** Market players must bring together software subsystems into a larger system (ECU/DCU but also at the vehicle level) and ensure that the developed functions meet specifications and fulfill their purposes consistently and reliably. This includes efforts for integrating and testing cybersecurity elements but also additional efforts for integrating and testing functional components due to enhanced security requirements.

For both categories, we look at two main subcomponents: operating systems and middleware, and functional domains.

Operating systems and middleware require the implementation of many security functionalities, including secure protocols, identity and access management, intrusion detection, and abstraction layers for crypto functions. These functionalities are then used by the functional domains (described below) to secure communications and avoid the creation of backdoors.

All **functional domains** need to be secured as well, but many of them can almost fully rely on the security functionality provided by the operating system and middleware. The most important areas needing additional security effort are ADAS and HAD, infotainment, and connectivity and security.

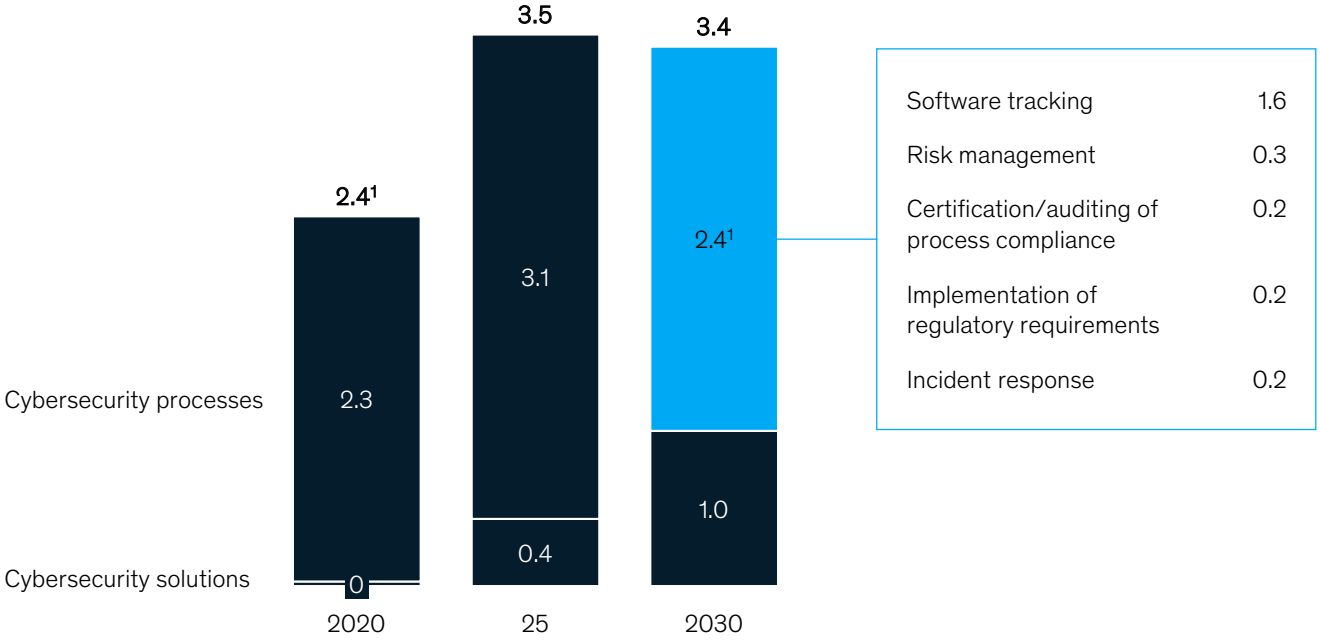
The software development market is expected to grow steadily at about 10 percent per year over the next few years to reach USD 5.3 billion in 2030 (see Exhibit 7). We expect to see a significant amount of competition – across player archetypes – related to ADAS and HAD in the automotive software market in general, and in the cybersecurity software market in particular.

Cybersecurity processes and solutions
Combined, the cybersecurity processes and solutions market – including both the personnel and tooling required to perform the activities – is expected to reach USD 3.4 billion by 2030 (see Exhibit 8). In the following, we break down this market into its two submarkets:

Exhibit 8

The cybersecurity processes and solutions market is mainly driven by software tracking; strong growth for vehicle SOCs is expected

Cybersecurity management and vehicle monitoring market size
USD billions



1 Sum does not add up due to rounding

Source: Analysis based on data from "Automotive software and electronics 2030 – Mapping the sector's future landscape," McKinsey, 2019.

Cybersecurity processes includes activities related to software tracking, risk management, regulatory requirements, certification/auditing of process compliance, and incident response. The market size will peak around 2025, driven by customers, quality expectations, and increased cyber threats, but also by the new UNECE WP.29 regulations on cybersecurity and software updates. Following initial investments to achieve compliance, investment and scaling efforts are expected to go down.

- **Software tracking.** The regulation lays out three requirements regarding traceability: i) inventory management of components and all software versions for each component, ii) verification of compatibility between different component versions in light of a software update, and iii) assessment of impact on safety-relevant components in light of a software update.
- **Risk management.** The upcoming regulation and standards will lay the foundation for developing and implementing risk guidelines. Regular evaluations will be needed to ensure that employees are following risk-management guidelines.
- **Implementation of regulatory requirements.** Automotive players must operationalize and adhere to the minimum requirements laid out in the respective regulations (e.g., UNECE WP.29) and industry standards (e.g., ISO/SAE 21434 and ISO/AWI 24089). This results in higher rigor, more functional requirements, and bigger investments – both upfront and ongoing – along the development lifecycle. Action on this front will take the form of more robust engineering requirements and architectural design with inherent security features.
- **Certification/auditing of process compliance.** Certification bodies will testify OEM compliance with industry standards and regulations.
- **Incident response.** Responses include analyzing anomalies, triggering the resolution of issues by the software R&D team, pushing software updates to the vehicles or back end, and managing communication with affected car owners. We assume that issues can be fixed via over-the-air updates and that fleet recalls will not be necessary.

Cybersecurity solutions involve vehicle SOCs, which monitor anomalies in connected vehicles (see text box). OEMs can either build and run SOCs in house or source them through external vendors, e.g., as a managed service. Vehicle SOCs need specialized personnel to operate them and deal with car security incidents.

The cybersecurity processes and cybersecurity solutions markets offer many opportunities to create new business. The area of process compliance will offer opportunities for testing, inspection, and certification providers across all subcategories.

Monitor and monetize – the concept and business opportunity of vehicle SOCs

SOCs are already well-established concepts in the enterprise IT world, but a relatively new concept for automotive software. Vehicle SOCs monitor anomalies in car systems, which are detected by intrusion-detection sensors within the car.

These sensors can, for instance, inspect data traffic on communication buses, monitor software processes, or track input/output operations of ECUs. The SOC is alerted to any detected anomalies, which are analyzed by specialists to distinguish between real threats and false positives. Incident management is triggered in the event of a confirmed attack, with countermeasures taken if needed, e.g., over-the-air updates.

Vehicle SOCs are still in their infancy. Their development requires answers to many questions, especially around pricing and support periods. The cost for fixing vulnerabilities or defending against attacks can vary extremely and is part of the "incident response" category. For the end consumer, support by an SOC and regular security updates to their vehicle's software over its full lifetime will become essential.

The market will present a wide range of opportunities over the next few years: from providing expertise, to offering tool support, to operating SOCs as a service. Given the importance of security updates and the monitoring of vehicle ECUs and DCUs, OEMs might see SOCs as an opportunity for generating additional revenue by charging a yearly fee after some years. This would be in line with the pricing model of already existing subscription services like traffic information or premium connectivity. But it remains to be seen whether OEMs will take this path or choose to provide lifelong services at no additional charge.

Strategic partnerships bring different automotive players together, joining forces on a variety of capabilities

Cybersecurity is very complex, and no company will be able to do everything on its own. Thus, partnerships will become essential, and we already see various kinds. The capabilities at the heart of current partnerships between automotive players and cybersecurity firms include:

— Manage vehicle cyber risks

— Secure vehicles by design

— Detect and respond to security incidents

— Provide safe and secure software updates

— Penetration testing and consultant services.

Our analysis of over 20 partnerships reveals the following insights (see Exhibit 9):

— Most partnership are between incumbent OEMs or tier-one/tier-two suppliers and start-up companies or security specialists.

— We don't see and don't expect large, interlinked networks, as is the case with autonomous driving.

— The partnerships cover all elements of cybersecurity capabilities.

— We see very few IT or OT cybersecurity companies entering the vehicle cybersecurity market. Possible reasons might be the latter's much smaller market size compared to the IT and OT cybersecurity market, or limited synergies due to the very different approaches to cybersecurity on a detailed level.

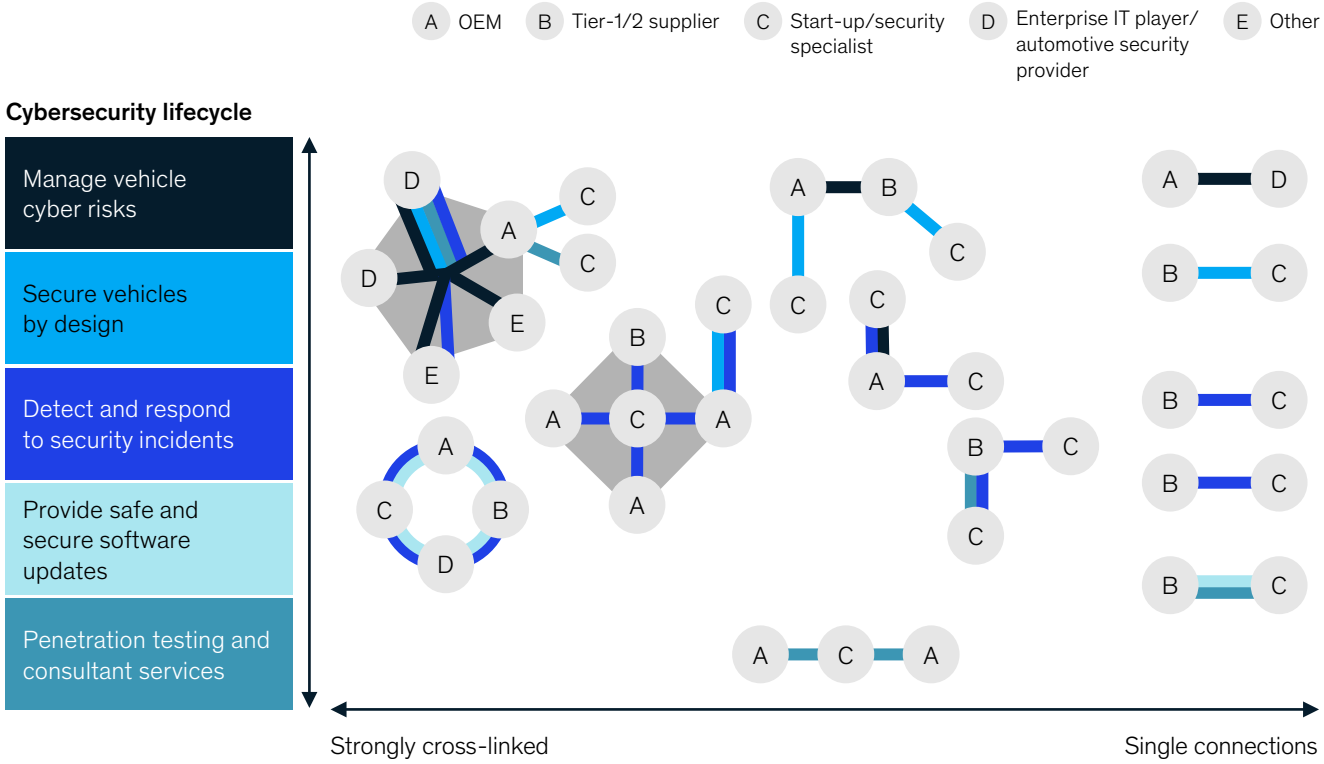
— Cybersecurity hardware business seems to remain with the incumbent semiconductor players, since we are not seeing any cybersecurity chip companies.

These partnerships offer OEMs and tier-one/tier-two suppliers access to cybersecurity products, services, and skills, but it will be key for them to build up cybersecurity knowledge internally. Every player must have deep cybersecurity architecture knowledge for its area of business, and its applications need to be secured individually. This can only be achieved if cybersecurity becomes an integral part of the culture.

Exhibit 9

Today's automotive cybersecurity landscape is interlinked with a broad variety of collaboration models

ONLY SELECTED PARTNERSHIPS SHOWN



Source: McKinsey analysis; press research

The need for partnerships is expected to open doors for start-ups, which normally would experience large market entry barriers; that is, the start-ups are too small for OEMs and tier-one suppliers to establish relationships with them. OEMs and tier-one suppliers often require a minimum size and business volume to ensure economic stability of business partners and keep the number of partners manageable.

We are already seeing many acquisitions, joint ventures, and collaborations between start-ups and OEMs/tier-one suppliers, and more are expected.

Getting started with navigating the changing industry landscape – pragmatic recommendations

For all players, it is important to get oriented early and define a strategy, but the strategic priorities, opportunities, and considerations will vary depending on where a company sits along the value chain. Potential pragmatic first steps for all players include:

Impact assessment. All automotive players should assess the impact of the new UNECE WP.29 regulations on their processes and business. This is necessary to ensure approvals of new vehicles types by OEMs after enforcement of the regulation begins (experts expect the EU to demand compliance starting in 2022 for new vehicle types and in 2024 for all vehicle types).

Capability mapping. Using a capability map, all players can identify areas of strength as well as areas for improvement, and define concrete needs. The needs can either be addressed by building up skills internally or sourcing them externally.

Prioritized implementation. Identified capability gaps need to be prioritized and critical paths for implementation must be outlined. In view of tight timelines, multiple new vehicle projects on the way, and numerous stakeholders, prioritization will be a key success factor, next to building up the required skills and workforce.

A company's understanding of both its internal strengths and the impact of regulation on its business set it up to identify potential business opportunities that arise from the evolution of cybersecurity. Potential opportunities include a range of products or offerings that could be developed and delivered to the market – this is especially true for suppliers. It is important to realize that not all aspects of the cybersecurity market will be accessible to all players. For example, the hardware business is expected to remain in the hands of semiconductor players for the foreseeable future.

In the following, we list selected areas which we believe will provide opportunities for a variety of players, including for those who have not yet been active in the automotive industry:

— **Vehicle SOCs.** The market for vehicle SOCs will emerge over the next few years. Similar to enterprise IT SOCs, we expect to see third-party vehicle SOCs, and software companies offering products to operate these SOCs.

— **Testing, inspection, and certification.** Like all other auditing, the cybersecurity auditing market will be in the hands of third parties. We expect to see a variety of companies become active in this market over the next few years, e.g., the big four accounting firms and firms specializing in auditing and certification.

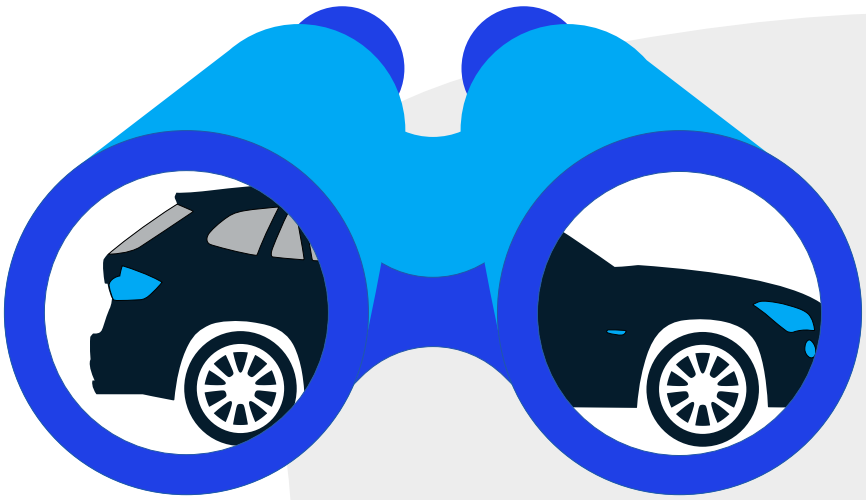
— **Software components.** The whole industry will be in need of security components, e.g., encryption algorithms, key management, and intrusion detection. Since it will be difficult to develop them all from scratch, there will be a market for ready-to-use software components as well as innovative solutions.

— **Software engineering and lifecycle tooling.** The productivity of software developers and testers can be significantly increased with the right tooling, and given the efficiencies to be gained, companies would likely be willing to pay for excellent products. There is a variety of tools that can help security specialists, including penetration-testing tools, software version management tools, and software tracking tools.

— **Innovative start-ups.** These will also try to access these markets but will likely face significant barriers to entry. Due to their size, it will be hard for start-ups to approach OEMs directly. They need to search for other ways to get access to OEMs, such as going through OEMs' venture capital funds or by partnering with suppliers.

Outlook

Cybersecurity has already gained the attention of automotive companies and will trigger a paradigm shift as companies need to start now to address customer demands, meet quality expectations, manage increasing cyber risks, and become compliant with the UNECE WP.29 regulations on cybersecurity and software updates. This requires a rethinking of cybersecurity and new working practices along the value chain. Cybersecurity will become nonnegotiable in the long run, and these trends create opportunities for all players to either differentiate themselves or generate additional business with new offerings. We are excited to see many new partnerships, fresh trends, and innovative products and services.



Appendix

How we derived the insights presented in this report

The insights of this report were generated by closely linking qualitative and quantitative research. To gain qualitative insight, we conducted interviews with industry experts. These interviews were complemented by workshops jointly organized by the Global Semiconductor Alliance (GSA) and McKinsey. The insights were then used to create a market model for cybersecurity in automotive and served as a basis for our qualitative findings.

For our quantitative market insights, we built bottom-up market models for each of the core components within the automotive cybersecurity market:

- Hardware (embedded hardware security modules (eHSMs), Trusted Platform Modules (TPMs))
- Software development (operating systems and middleware, functional domains)
- Services (engineering services, process compliance services, vehicle security operations center (SOC) services)

Further details on and results of the market models are presented in Section 4. Details on the methodology are provided in this section.

List of abbreviations

ACES	Autonomous driving, connected cars, electric vehicles, and shared mobility
ADAS	Advanced driver-assistance systems
DCU	Domain control unit
ECU	Electronic control unit
eHSM	Embedded hardware security module
E/E	Electrical/electronic
HAD	Highly automated driving
IP	Intellectual property
IT	Information technology
OEM	Original equipment manufacturer
OS	Operating system
OT	Operations technology
R&D	Research and development
SOC	Security operations center
TPM	Trusted Platform Module
UNECE	United Nations Economic Commission for Europe

Key aspects of the market model

Within these models, we distinguish between the following domains: ADAS, body, chassis, connected services, connectivity and security, energy, HAD, infotainment, middleware, OS, and powertrain.

The base data of all three models in our report builds on the data of a previous McKinsey report from 2019: "Automotive software and electronics 2030 – mapping the sector's future landscape."

We gained the quantitative market insights in this earlier report by building bottom-up market models for each of the core components within the automotive software and E/E market. In addition, we further validated our data and findings by integrating findings from market research companies such as Strategy Analytics and IHS Markit.

In the 2019 report, the number of vehicles produced each year is provided in a separate model, incorporating data from the latest McKinsey Center for Future Mobility market outlook and scenario analysis, and the McKinsey EV market model.

Cybersecurity hardware components market model

The hardware model uses the report's prediction of the number of ECUs and DCUs installed by 2030. Each ECU will be assigned an eHSM and each DCU will be assigned a TPM. A ramp-up curve until 2024 ensures a smooth increase of numbers.

Cybersecurity-related software development efforts market model

The software development model uses total automotive software development spend as its main input. For each domain, we collaborated with industry experts to assess the share of cybersecurity within this market. The results are again modeled on a smooth ramp-up curve showing the increase in software development investments over the next several years.

Cybersecurity processes and solutions market model

Cybersecurity processes. This portion of the model analyzes software tracking, the implementation of regulatory requirements, risk management, incident response, and certification/auditing of process compliance. The scope of these buckets has been described above.

- Software tracking and the implementation of regulatory requirement buckets only contain efforts related to or caused by cybersecurity and are both calculated using the same logic as for engineering services, except that the ramp-up curve peaks at around 2021/2022 and saturates at a lower value, modeling the higher initial effort during those years.
- Risk management and incident response are calculated as a share of the software developer workforce. Again, a smooth increase over the next several years is assumed.
- The certification and audit efforts follow the same logic as incident management, except that we expect a peak in effort in the next few years with a lower steady state afterwards.

Cybersecurity solutions. The solutions market contains vehicle SOCs, and its market size is based on the total number of new vehicles, the monitoring cost per vehicle and year, and the adoption rate of vehicle SOCs. The total number of new vehicles is taken from the 2019 McKinsey report. Again, a smooth adoption rate with a steady state of 100 percent after 2024 is assumed. We estimated a service time frame of at least ten years; that is, no cars will reach the end of its lifetime until 2030.

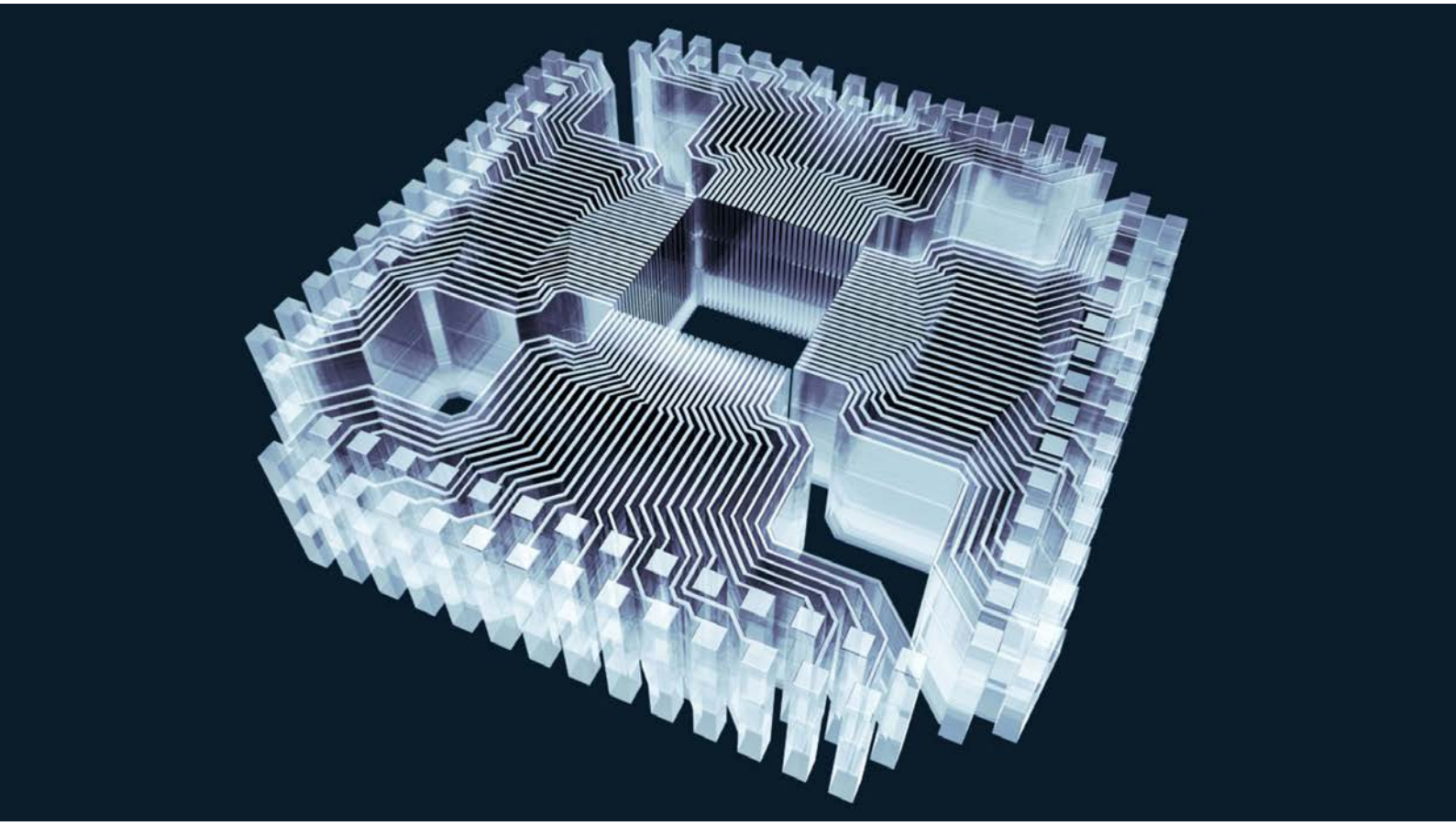
To pressure-test the results of our modeling, we conducted a series of interviews with Global Semiconductor Alliance members in North America, Europe, and Asia. Based on their feedback, we iterated the models towards the version presented in this report.

Will quantum computing drive the automotive future?

As quantum computing comes closer to reality, automotive players are exploring its potential.

September 2020

by Ondrej Burkacky, Niko Mohr, and Lorenzo Pautasso



Buzz and hype aside, something is going on in quantum computing (QC) that is hard to miss, and the technology will have real implications for the automotive industry. Much of the excitement relates to recent scientific leaps in the field as well as the development of the first industrial use cases, including those in the automotive and transportation sectors.

Recent headlines about QC reflect the excitement. IBM drew attention across the tech world when it announced the creation of Q System One, a quantum computer confined to a nine-foot cube, in 2018. In another big advance, D-Wave Technologies announced a QC chip with 5,000 "qubits," more than doubling its own previous 2,000-qubit record (see sidebar "What's different about quantum computing?").

The automotive industry has been following these developments, since QC provides computational improvements that could boost capabilities across the value chain. Several OEMs and tier-one suppliers have already begun investigating QC's ability to benefit the industry and resolve some existing issues, including those related to route optimization, fuel-cell optimization, and material durability. Several are now showcasing the first pilot use cases. Volkswagen, for example, has partnered with D-Wave to demonstrate a traffic-management system to optimize the individual travel routes of nine public-transit buses during the 2019 Web Summit in Lisbon, Portugal. Bosch, a German tier-one supplier, has acquired a stake in Zapata Computing, contributing to a $21 million Series A investment in the Cambridge, Massachusetts-based quantum start-up.

Although QC has great potential in the automotive sector and could translate into billions of dollars in value, OEMs and other stakeholders face some obstacles. The novelty of this technology combined with the relatively small market that has emerged thus far have prevented many automotive players from developing a clear QC strategy. To assist them, we reviewed QC's maturity and its potential in the automotive sector. We also examined opportunities for automotive stakeholders and potential next steps.

Gauging quantum-computing maturity

QC is undoubtedly on its way, but adoption at scale will not occur until five to ten years from now. Industry players now view QC in terms of four horizons with distinct milestones in each:

— Achievement of quantum supremacy. We likely reached this point in 2019.[1]

— Demonstration of the first quantum advantage. This step will involve developing practical use cases that will probably perform simulations of quantum phenomena. The first pilots on

What's different about quantum-computing applications?

Instead of using traditional bits as information-processing units, QC depends on quantum bits or "qubits." Players can physically generate qubits many ways, such as by trapping supercooled calcium ions in a magnetic field and creating interlinked superconducting capacitor circuits. Possible effects observed on a quantum level include superposition (how waves either add to each other or cancel out, as in noise-canceling headphones) and quantum entanglement (where particles remain connected such that an action on one will affect the other, even at great distances).

Shor's algorithm shows how much QC can improve processing time. Designed to run on quantum computers to find the prime factors of a given integer, it is almost exponentially faster than the best conventional factoring algorithm.

[1] A large tech company claimed that it achieved quantum supremacy in 2019. Some other companies have contested this claim.

quantum advantage, such as Volkswagen's traffic optimization, are emerging today. Complex problem solving that requires many qubits working together will become feasible in 2035 or later.

— Attainment of broad quantum advantage. This is the point when it will become commercially viable to invest in programming quantum-computer software to tackle specific problems. Some predict this milestone will occur around 2030.

— Creating the quantum Turing machine. The final step involves building a full, universal quantum computer with quantum memory and random-access memory. The Turing machine will run on as many qubits as desired and can perform any algorithms. It should be viable in one to two decades.

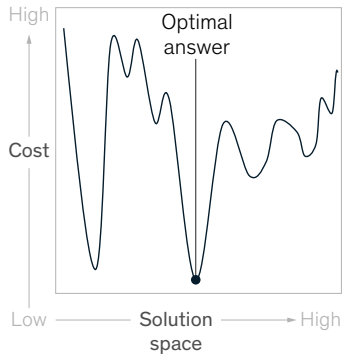
Even over the long term, QC will not likely replace existing high-performance computing (HPC), nor will the first attempts at value creation rely on at-scale QC devices that solve full problems. Instead, we believe that successful QC use cases will rely heavily on hybrid schemes over the next decade (Exhibit 1). First, a small QC-based subroutine will quickly generate a rough answer for an optimization problem. A conventional HPC will refine this answer with a narrower set of variables. In this way, programmers can employ early-stage QCs to run HPCs more efficiently.

Exhibit 1

In hybrid schemes, high-performance computing is used for the bulk of work, while quantum computing is used to analyze a subset of data.

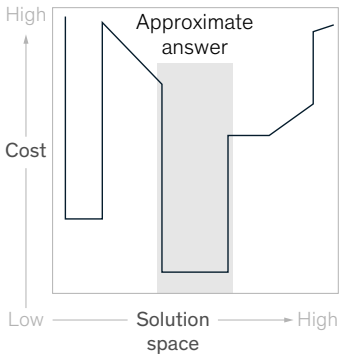
How hybrid schemes work

1. **Transfer into a computational problem;** Example: find best (lowest cost) option among billions of possible combinations



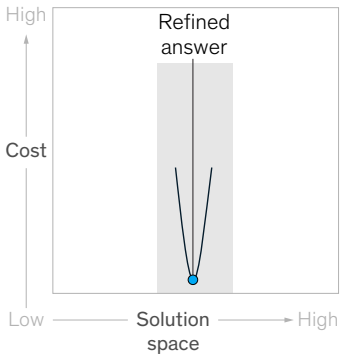
Practically unsolvable with conventional HPC; to find right answer with certainty would require calculating cost for all combinations

2. **Do first iteration with quantum computer to get an approximate answer;** Example: quantum-computing (QC) step takes 1% of overall computing time and accounts for 3% of overall cost; remainder is for high-performance computing (HPC)



Fast but provides only rough assessment of complete solution space

3. **Fast refinement with super-computer;** Example: QC step accounts for 99% of overall computing time and 97% of cost; remainder is for HPC



Solvable sometime in next few years[1] using smart hybrid approach that assesses subset of solution space

[1]Depending on problem size; at earliest, 2022.
Source: McKinsey analysis

Automotive quantum-computing applications: Peeking under the hood

Currently, one-tenth of all potential QC use cases under exploration could benefit the automotive industry. In fact, automotive will be one of the primary value pools for QC, with a high impact noticeable by about 2025. We also expect a significant economic impact of related technologies for the automotive industry, estimated at $2 billion to $3 billion, by 2030. Most of the early value added will come from solving complex optimization problems, including processing vast amounts of data to accelerate learning in autonomous-vehicle-navigation algorithms. In later years, QC has the potential to have a positive effect on many areas in the automotive industry, such as vehicle routing and route optimization, material and process research, and the security of connected driving. Moreover, QC can also provide a boost to automotive players transitioning into the electric-vehicle (EV) era by notably accelerating research and development of novel technologies (see sidebar "How quantum-computing applications can accelerate the EV transition").

Near-term opportunities for QC—those from 2020 through 2025—will most likely surface in product development and R&D. Relevant use cases will primarily relate to solving simple optimization problems or involve parallel data processing for simple quantum artificial-intelligence/machine-learning (AI/ML) algorithms. These quantum-computing applications will be executed as part of a hybrid solution, where bits of a larger problem, processed by an HPC, are outsourced to a quantum computer and results are fed back into the HPC flow. Possible optimization use cases include the combinatorial optimization of multichannel logistics, highly local traffic-flow optimization, and improvements in vehicle routing. Quantum AI/ML might involve the time-efficient training of autonomous-driving algorithms due to an increase in the parallel processing of large amounts of data.

Midterm plays, from 2025 through 2030, will probably center on the following:

— *Quantum simulations.* Focus areas will include the simulation of complex partial differential problems, such as those dictating heat and mass transfer, fluid dynamics, and compressible flows. Simulating material properties on the atomic level will also become relevant, for example to improve the selection and development of battery and fuel-cell materials.

How quantum-computing applications can accelerate the EV transition

The ascent of electric vehicles (EVs) entails new opportunities and challenges for all players across the automotive value chain. Suppliers whose core competencies are not central to EVs, such as transmission or fuel-tank and tubing manufacturers, can leverage QC to gain a competitive edge in producing goods outside of their traditional playing field. For example, companies that traditionally produced fuel tanks and tubing can apply their knowledge of liquid storage and transportation systems to the production of cooling circuits for EV batteries. The required innovation in tubing materials, as well as the potential development of novel cooling liquids and tube-routing strategies, could be achieved through a hybrid of HPC cluster and a quantum computer. This hybrid could help efficiently solve both quantum simulation and optimization problems.

Other key players across the EV value chain that can leverage QC to advance research and development include battery and fuel-cell manufacturers, which could leverage quantum simulations in material- and chemical-process research. Likewise, software manufacturers, could improve predictive maintenance and autonomous-driving algorithms through quantum AI/ML.

The novelty of quantum computing combined with the relatively small market that has emerged have prevented many automotive players from developing a clear QC strategy.

— *More complex optimization problems.* These will encompass high degrees of freedom. For instance, they may minimize the possibility of supply-chain defaults, optimize citywide traffic flow, or solve large-scale multimodal fleet-routing problems.

— *Complex quantum AI/ML.* These applications will be able to process even larger amounts of data. For example, they might lead to novel control processes by identifying new variable correlations, enhancing pattern recognition, and advancing classification beyond the capabilities of the current HPC cluster.

Over the long-term, from 2030 onward, quantum-computing applications will build on at-scale access to universal quantum computers. Prime factorization algorithms to break common encryption keys will therefore be universally available. The focus will likely move toward digital security and risk mitigation as players try to prevent the quantum hacking of communications in autonomous vehicles, on-board electronics, and the Industrial Internet of Things. The cloud-hosted navigation systems of shared-mobility fleets will improve their coverage algorithms through regular training enabled by QC.

Opportunities for quantum-computing applications across the automotive value chain

Stakeholders across the automotive value chain will be able to leverage QC, mostly as part of a hybrid solution with HPC clusters, to solve problems that are specific to their role and position in the industry's value chain (Exhibit 2). Below are a few examples.

'Tier n' suppliers

Companies can optimize their supply routes involving several modes of transport using algorithms developed through QC. Other applications include the development of new technologies, including those for improving energy storage and generative design. QC could also help suppliers improve or refine the kinetic properties of materials, such as lightweight structures and adhesives, or develop cooling systems. For instance, QC could help companies simulate chemical processes and fluid dynamics, allowing them to obtain important insights.

Warehousing, distribution, and supply-chain management

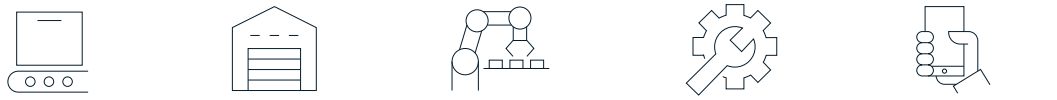
QC can improve logistics across the value chain. For instance, it can optimize the routing of warehouse robots or increase the accuracy of demand forecasting to tier-n suppliers by simulating complex economic scenarios.

OEMs

Automakers could use QC during vehicle design to produce various improvements, including those related to minimizing drag and improving fuel efficiency. They could also use QC to perform advanced simulations in areas such as vehicle crash behavior and cabin soundproofing, or to "train" the

Exhibit 2

Quantum computing may enhance key steps across the automotive value chain.



"Tier n" suppliers
With quantum-computing (QC) support, suppliers can develop new technologies, such as battery materials and cooling systems; supply routes can be optimized, including those that involve multiple forms of transport

Warehousing, distribution, and supply-chain management
QC can help improve the accuracy of demand forecasting and warehouse logistics across the value chain

OEMs
OEMs may use QC to optimize their vehicle designs, enhance autonomous-driving software, and improve safety (eg, through simulations of vehicle crash behavior)

Dealerships and repair shops
Together with OEMs, dealers can enhance predictive-maintenance software through QC-supported training of machine-learning algorithms

Service providers
Shared-mobility providers can use QC for optimal vehicle routing to improve fleet efficiency and availability, or to predict geographical demand by simulating complex economic scenarios

algorithms used in the development of autonomous-driving software. Given QC's potential to reduce computing times from several weeks to a few seconds, OEMs could potentially ensure car-to-car communications in almost real time.

Dealerships and repair shops
OEM dealers can employ QC to support the training of machine-learning algorithms that will enhance predictive-maintenance software.

Service providers
Shared-mobility players can use QC to optimize vehicle routing, thereby improving fleet efficiency and availability. Another critical use involves helping mobility providers simulate complex economic scenarios that allow them to predict how demand will vary by geography.

Assessing the QC market

We estimate the overall market value of QC services at $32 billion to $52 billion in 2035. Through that year, about 10 percent of this value will come from spending by advanced-industry players, including automotive companies, that want to capture benefits from QC.

The value chain for quantum technology is in flux, and it is still unclear which companies will emerge as the top players at each step of the QC value chain. There are now about 100 companies in the space. Some of these companies, including D-Wave, IBM, Microsoft, and Rigetti Computing, build QC hardware. Around 80 percent of companies are start-ups that aim to bridge the gap in the value chain between hardware manufacturers and end users by translating conventional problems into a quantum logic and by building hybrid architectures that combine HPC with QC steps.

Many stakeholders will shape the QC market, including hardware and software players and their enablers. QC-software users will also determine how the industry evolves.

Hardware. One-third of QC companies focus on hardware development. Players include global technology giants and start-ups, mainly based in the United States. It is unclear exactly how the industry will configure hardware for quantum computers over the next 15 years, because players are currently developing several competing approaches, and these will evolve over time. Many hardware companies currently strive to deliver QC as a service via the cloud, making it unlikely that users will have to set up their own hardware. Automotive companies will also have to decide how to access QC services in the short term, with on-demand cloud capacity being the least expensive and most flexible option.

Software. Roughly half of the participants in the QC value chain develop software. In contrast to hardware suppliers, start-ups make up the bulk of these players, with most in Europe and North America. Large hardware players, such as D-Wave and IBM, also develop QC software. Some programs are used for automotive use cases, such as process-design and hardware-design optimization. Such solutions are likely to be used at scale within the next five to ten years. Small players, such as the German start-up Avanetix, also focus on developing software solutions for process optimization. Some, for example, are designed to optimize the supply chain.

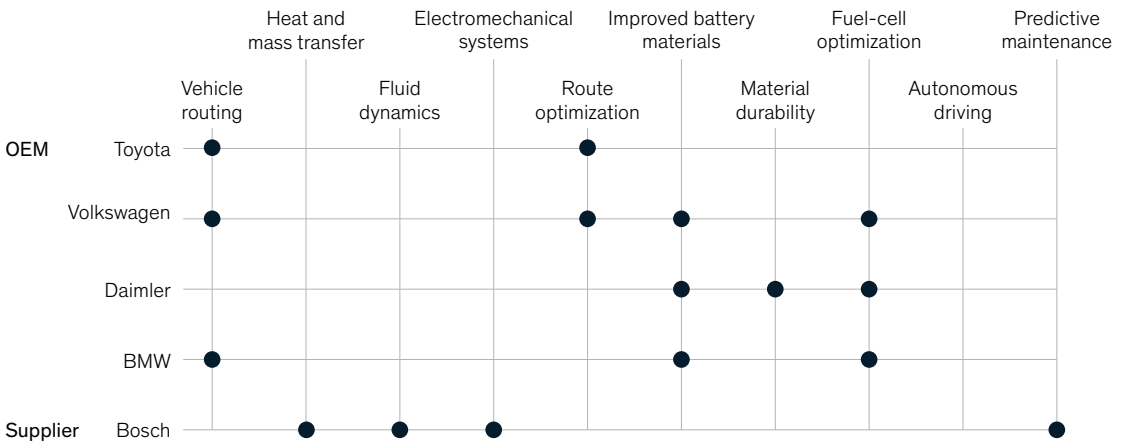
Enablers. One-fifth of companies in the QC value chain provide enabling solutions. Their offerings include existing components, such as cooling units, processing tools for making qubits, and the materials that compose qubits. This area could become a potential playing field for some upstream automotive suppliers, including tier-two and tier-three vendors, which produce control units and thermal solutions that are potentially transferrable to quantum computers. Automotive suppliers will not immediately profit from large-scale-production opportunities, since QC is still in its infancy, but they will over the long term. We expect enablers to become more relevant as the QC industry matures, gains scale, and one hardware approach begins to dominate.

QC software users. Many automotive players have publicly announced that they are actively pursuing QC research, sometimes partnering with companies in the upstream part of the QC value chain. Some announcements have come from BMW, Daimler, and Volkswagen. They all investigate quantum simulation for material sciences, aiming to improve the efficiency, safety, and durability of batteries and fuel cells. Bosch focuses its research on solving partial differential problems through QC. While quantum-computing applications based on this research may still be five to ten years down the road, OEMs have already demonstrated successful QC pilots in some areas, such as vehicle routing (Exhibit 3).

Exhibit 3

Quantum computing within the automotive sector is currently limited to select applications, such as traffic-flow optimization and routing.

Quantum-computing applications in the automotive sector (selected companies)



Source: Public announcements; McKinsey research

Moving forward with quantum-computing applications in automotive

As with every new technology, many uncertainties persist about QC, particularly when it comes to competing hardware technologies. QC teams may initially receive mixed responses regarding their advances, and some may find it difficult to move beyond negative reactions. With the QC-hardware industry making rapid progress, it seems unlikely that even the world's largest automakers will have their own physical QC systems, at least initially. Instead, they will probably develop their own algorithms and run them on the cloud-based QC systems of their partners.

One early challenge for automotive players involves building a solid cadre of talent. Since the initial need is probably small—say, three to five experts and "quantum translators" working full-time on QC research and applications—filling this gap seems doable. For example, training the sharpest IT people in QC language and translating classical problems into quantum-ready formulations may do the trick. As team members begin to immerse themselves in the technology, they should be allowed to experiment. Their work will primarily focus on using QC to enhance HCP, rather than automating manual work. Overall, the resources required to begin a QC initiative will be extremely small in the context of a large company's IT budget.

The need for an evolving strategy for quantum-computing applications

Given the uncertain pathway forward for QC, companies must understand their full range of options regarding the technology over different time horizons. While QC will not be commercially viable at most businesses for at least ten years, automotive players should still look for opportunities over the short term (the next one to two years). As a first step, they could begin to scout for a position in the value chain, build research partnerships and intellectual property, assemble a small team, and establish routines. Potential collaborators could include large tech companies, academic institutions, government laboratories, and start-ups manned by quantum-software developers and other specialists. In the short, medium, and long term, companies should also scout for potential opportunities for investment or joint ventures, keeping in mind that the market has many investors focused on only a few targets and that the stakes are high.

Over the medium term (five to ten years from now), players should prioritize application development and build focused capabilities. In the process, they should select front-runners, scale teams to midsize, and make the first pilots and prototypes operational. They should also strive to become innovators in a focus area.

In the longer term, over ten years from now, businesses should gain a technological edge through QC, build a competitive advantage in focus fields, and begin to expand their core capabilities.

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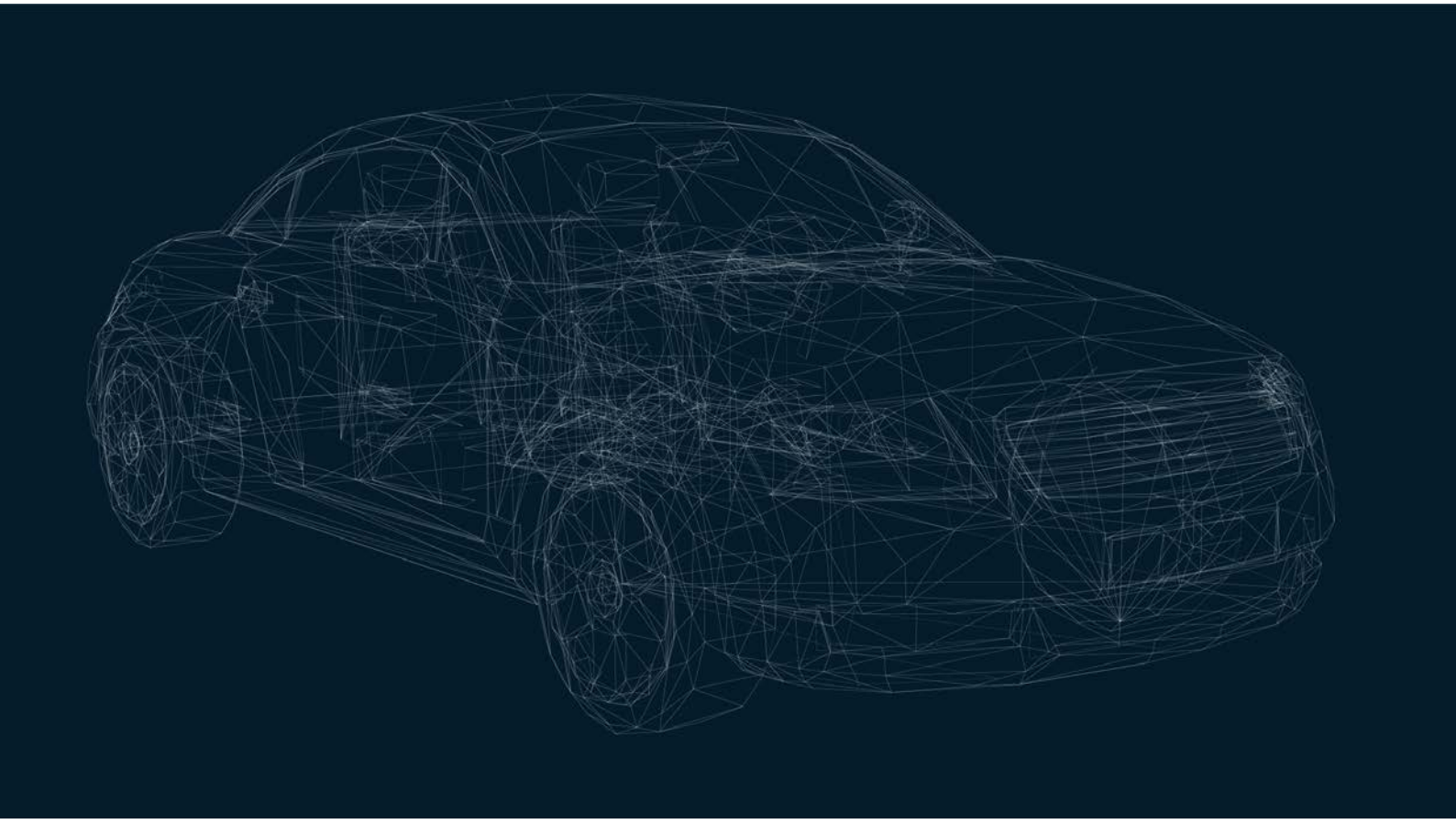
Mastering automotive software-launch excellence

Automotive players can crack the code on superior launch performance by reducing complexity and increasing robustness in embedded software development.

December 2019

by Ondrej Burkacky, Georg Doll, Dominik Hepp, and Rupert Stuetzle



Mastering a successful product launch with respect to time, cost, and quality is a core capability for every organization. However, product-launch delays have multiplied rapidly in recent years in the automotive industry—often with hundreds of millions of euros or dollars at stake for an OEM or tier-one supplier. And that doesn't include the damage to a company's brand and reputation.

The failure to launch smoothly can jeopardize an entire company's competitiveness and brand trust, while disrupting its financial performance. This problem inflicts new industry entrants and established OEMs alike. Based on our research, the central reasons for automotive product-launch delays are the increased complexity of software and electronics and an approach to software development that fails to keep up with growing system-level complexity. The following article outlines best practices and tools to overcome these shortcomings and ensure successful product launches.

Growing launch problems highlight the increased importance of software

The automotive industry faces a multitude of technology-driven disruptions. Software is becoming progressively more important as it increasingly determines the value of a car. The technologies driving this transformation include autonomous vehicles, connectivity, electrification, and shared mobility (ACES), which offer new opportunities for growth and disruption.

In other words, the digital car is finally arriving—over-the-air updates replace auto-shop visits and suggest new business models while software features replace formerly differentiating factors such as engine characteristics or suspension tuning. Therefore, the capability to manage the development of embedded software systems to deliver the right functionality on time and within budget becomes a differentiating asset.

In this environment, launch delays will become increasingly important vis-à-vis the value at stake, which can add up to hundreds of millions of dollars for an OEM. And that's not counting the damage to a company's brand and reputation from delays. Additional opportunity costs can also arise, such as when a delayed launch leads to additional homologation efforts from increased emission standards.

McKinsey research suggests that the global automotive-related software market will roughly double between 2020 and 2030, outgrowing the automotive market in general (Exhibit 1). This dynamic will further increase the risk of software-driven launch problems.

Handling complexity

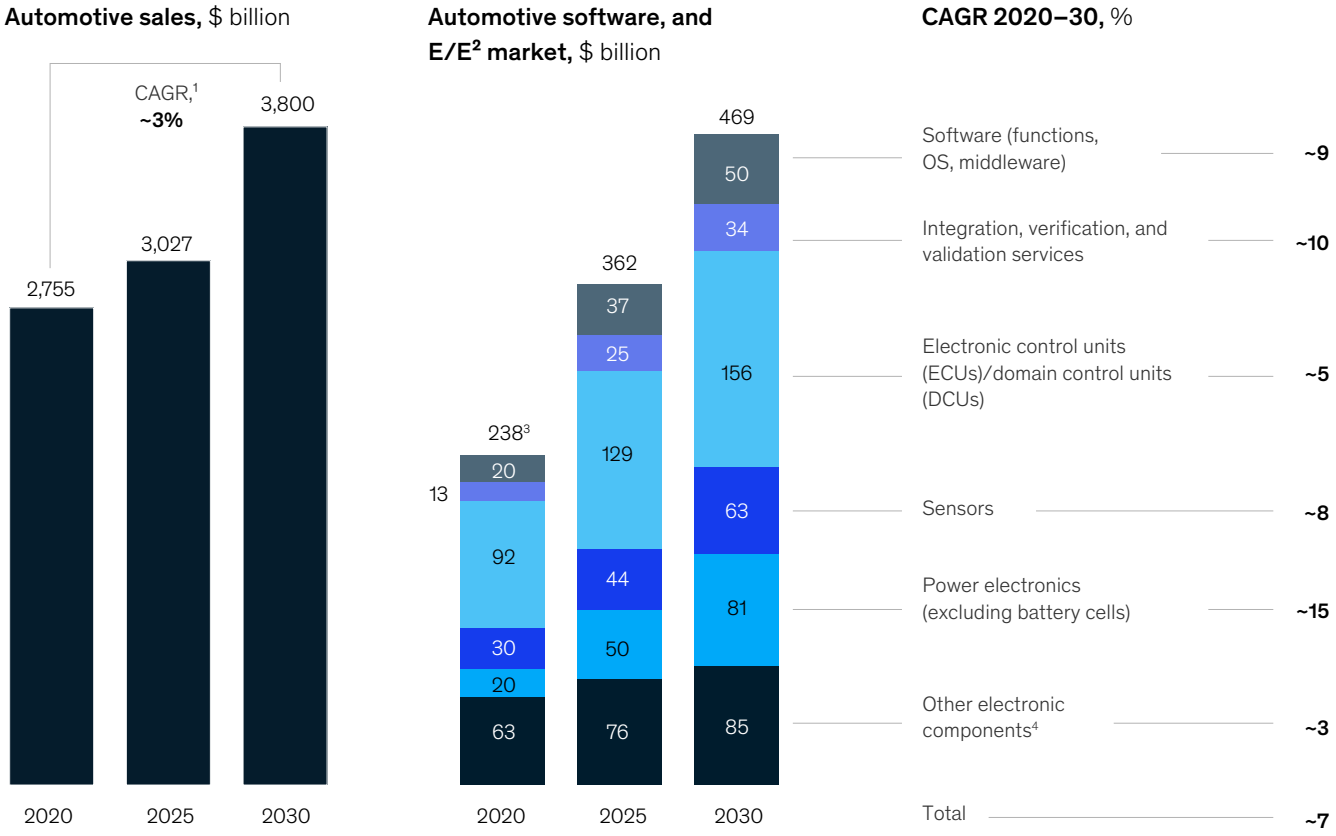
Product complexity has significantly increased during the past ten years, a development that will likely accelerate through 2030. New technological trends like ACES require not only the development of new features but also changes in the underlying electric and electronic architecture. Such shifts call for changes in the industry's collaboration models, with suppliers significantly widening the OEM–supplier interface. In addition, the introduction of new platforms for electric and autonomous cars further complicates the product portfolios of automotive OEMs and tier-one suppliers. Other confounding issues include required updates and enhancements to established internal-combustion-engine (ICE) platforms, including more stringent emission limits in the European Union, such as Euro 7, and the new regulation on cybersecurity and software-updates from the UN Economic Commission for Europe (UNECE).

Furthermore, it remains unclear which platform will be the most successful in the coming years. Will hybrid electric vehicles (HEVs), battery electric vehicles (BEVs), or ICEs win? Amplified via modern regulation requirements such as the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) and Euro 7, the rising complexity levels of products and platform architectures demand rigorous decisions and thoughtful management.

Today, many OEMs must contend with the greatest variety of levels ever in their product portfolios, not only regarding the diversity of models and variants

Exhibit 1

The automotive electronic and software market will see strong growth through 2030, driven by power electronics, software, ECUs, and DCUs.



[1] Compound annual growth rate.
[2] Electrical and electronic components.
[3] Figures may not sum to 100%, because of rounding.
[4] For example, harnesses, controls, switches, displays.

Source: Revenue forecasts based on vehicle volumes from IHS Markit (Automotive), Light Vehicle Production Forecast, Oct 2018, pull completed on Nov 6, 2018; McKinsey analysis

but also in the underlying software platforms. OEMs have begun to cut down complexity, but they remain at the start of this journey.

Handling the workload

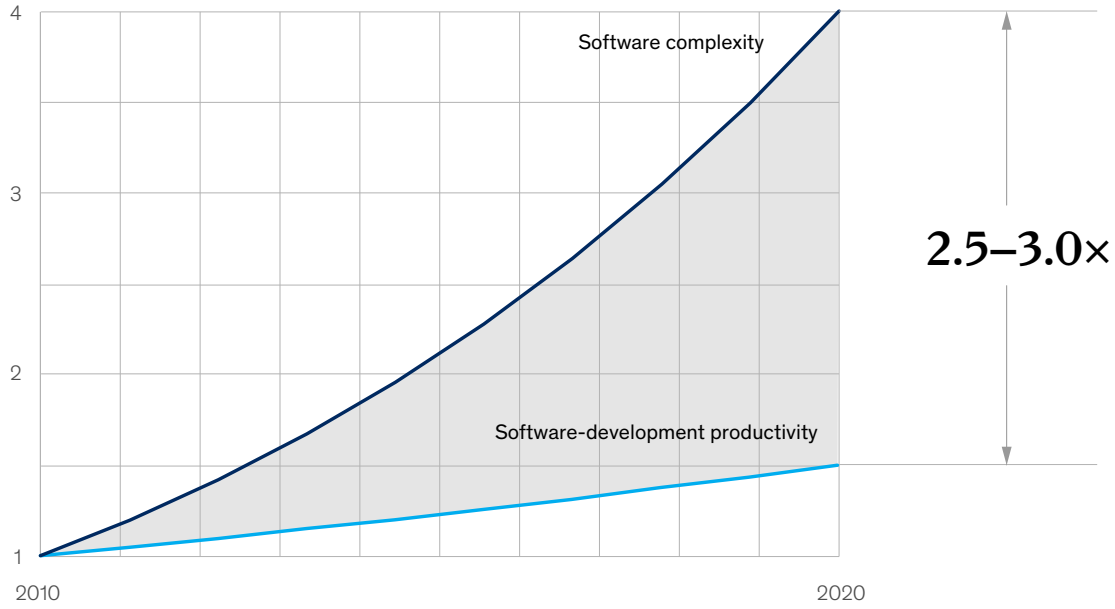
McKinsey research shows that the complexity for mission-critical software features such as those for autonomous-driving functions is currently growing at double to triple the speed of software-development productivity (Exhibit 2).

Traditionally, automakers have managed their interactions with suppliers along well-defined system limits such as physical electronic-control-unit (ECU) boundaries, the functions an ECU provides, and protocol definitions. However, with software arriving in the automotive supply chain, these interfaces are changing and, as a result, their complexity is increasing significantly. Furthermore, new methodologies like agile development call into question traditional development approaches. For example, many OEMs have traditionally specified

Exhibit 2

Growth in software complexity more than doubles the growth in software-development productivity.

Relative growth over time, for automotive features, indexed, 1 = 2010



Source: Numetrics

their requirements at the control-unit level and now must do the same for software components. As a result, their attempts to integrate software systems with suppliers often lack depth and rigorous management. What's more, the OEMs' development tools often don't include features needed to monitor supplier progress effectively, such as defect tracking. Likewise, cross-supplier dependencies usually require a holistic understanding at the component-architecture level—insights that current OEM systems do not support and teams often lack.

To set up an effective, shared launch-management approach for embedded-software-system solutions between manufacturers and suppliers, companies need to understand the requirements for launch readiness. Consequently, many OEMs often proactively search for ways to involve first- and second-tier suppliers to share the complexity load.

Mastering software-launch excellence

OEMs and suppliers must master challenges across four dimensions to achieve software-launch excellence (Exhibit 3):

— *Improved product readiness.* Ensure full maturity and quality when integrating software-enabled functionality from different suppliers and when integrating the full system. This requires the definition of launch-critical features, testing procedures, and product-release effectiveness: debugging, acceptance testing, version control and management, and over-the-air updates. Also, secure integrated product-development processes are needed for both hardware and software.

— *Enhanced supplier readiness.* Focus on timely availability and alignment with quality requirements for software features and

Exhibit 3

The launch excellence framework entails four main components.

Securing software functionality

1

Product readiness

Secure full software maturity and quality level on system level in line with specifications

2

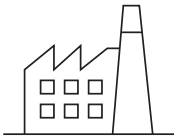
Supplier readiness

Secure full availability of features in line with specifications and quality requirements

3

Securing development process readiness

Secure cross-functional governance for entire launch phase



4

Production readiness

Secure feature availability from a production perspective, eg, end-of-line testing, diagnostics, and software-update capability

Source: McKinsey analysis

establish key performance indicators (KPIs) along the entire software-development process, with a concentration on early indicators for launch risks. Focus areas include the ramp-up of capabilities, the guarantee of resources, the conformity of features to specifications, the determination of release processes, and the definition of selected logistics concepts like test execution planning.

— *Robust software-development processes and project management.* Guarantee the robustness of embedded and integrated product-development processes for both hardware and software across OEMs and suppliers. To do this, establish a cross-functional governance system for the entire launch phase jointly with suppliers. To drive the impact across all phases of a launch, it makes sense to introduce a clear governance structure with responsibility matrices, change-control boards, and KPI systems, for example.

— *Focused production readiness.* Ensure feature planning from a production-readiness perspective. The essentials for a successful project launch include production-enabling features such as end-of-line testing, diagnostics, and software-update capability functions. Another critical element involves exactly aligning milestones along the different production launch steps.

Solution approaches

Two approaches for avoiding launch delays can be explored. One, the proactive solution, involves front-loading the setup in early project stages, shortly after the start of a development project. The other, the reactive solution, focuses on debottlenecking, feature prioritization, and setup recovery in later project stages, mostly within the last 12–24 months before a targeted start of production. Our research has identified and detailed a set of actions for each approach.

— *Proactive approach* OEMs and suppliers get ahead of the challenge, proactively laying the foundation for software-launch excellence. Building capabilities in managing complexity through full-stack transparency will pay off.

— *Reactive approach* OEMs and suppliers need to turn around an already-delayed running development project that is unlikely to keep

its launch date. Companies must implement mitigation measures under increased time and financial pressure.

Proactive approach: Front-loading at early-phase delays

To ensure product readiness, automakers must sharpen their requirement specifications and integration capabilities. That means developing a policy to optimize and manage requirements, which should include a transparent, cross-functional collaboration in requirement management. They should pursue the early, iterative development of functional and value requirements, and make a neutral and systematic evaluation of the requirements based on cost and value. Furthermore, OEMs need to adhere to a minimum feature-set plan for integration, development, and sourcing. Following a software-industry maxim, they should "build enablers first, then functions on top" to avoid redundancy and gaps among enablers. Other suggestions include enhancing frequent automated testing by introducing and establishing a new software-development tool chain. The tool chain should support automation that could reach from artificial-intelligence-based ticket assignment to automated regression tests on target hardware. They should also start to build a forecast model to monitor task progress based on input from task-driver trees, dependencies between activities and milestones, early indications of tracking, and resource configurations.

Ensuring supplier readiness requires companies to establish a collaboration model between internal and external developers in a continuous-integration mode. Companies need to align supplier interfaces, clearly defining and establishing them at all levels of supplier interaction, detailing milestones, and synchronizing flows along the phases of development. In many situations, development and testing logistics should take the form of reviews, to ensure the timely availability of test vehicles, prototypes, or in-the-loop systems with the right software version installed.

Software-development processes and project-management readiness require automakers to run criticality assessments along the integration path, including risk assessments. This risk-assessment process should include cross-functional discussions via a dedicated workshop format, as well as a detailed checklist for action items. Developers can use visualization techniques to create action lists for high-risk parts and suppliers and to plot an overview of the risk-assessment process on a risk matrix.

Companies should establish a KPI-based early-warning system, applying a systematic approach early to pick up warnings of upcoming risks. One important aspect of this step involves choosing the right indicators in the KPI set, such as requirement-implementation rates, unit-test coverages, and defect-detection and -resolution rates. When using agile-development methodologies, burn-down velocity offers a good way to determine a project's actual development status. Organizations should also establish a budget and development plan and use deviations as early indicators. Best-practice companies usually create a cockpit that can automatically track relevant KPIs from the current launch phase, enable abstraction, and ensure adequate coverage from development to the business-unit level.

They also employ predictive analytics to generate greater transparency as far as scheduling the required resources at the start of the project, and to assess plan risks resulting from unrealistic assumptions. Managers need to answer the questions of what risks exist in the current project plan, and what the optimum plan would look like. Output could include forecasts of the personnel needed by role and project phase, for example, or a quantification of the risks that arise due to unrealistic productivity assumptions.

Reactive approach: Debottlenecking delays at a later stage

Product readiness in this case requires automakers to prioritize critical features and descope content along the development timeline. They should consider staged software releases, focusing on diagnostic and factory requirements first and then derisking the production start, and plan early software updates before delivering the first cars

to customers. They must also ensure pragmatic, frequent tests and an efficient planning of the availability of test assets, including test boards, hardware-in-the-loop systems, and test vehicles.

Supplier readiness results from rigorous defect tracking and rigorous quality control for prioritized features. Automakers should also ensure resource availability and that key suppliers have appropriate skill sets.

To promote project-management readiness in the context of embedded-software-development projects, OEMs should set up a digital project-control board, which can help them achieve two objectives. First, it can generate full transparency per cluster for all required software functions. It can also help plan and communicate upcoming release content and the start of production. It provides the testing status for all software functions, including a direct link to error-management systems. Second, the project-control board makes possible analytics-enabled error pre-analysis and management. This allows automakers to monitor the inflow and outflow of error tickets efficiently to ensure a deadline-based burn down. It allows users to monitor ticket transitions between different development teams and helps reduce inefficiencies during root-cause analysis of problems. Of course, companies must augment these KPIs depending on the project situation and data availability.

Automakers and suppliers can also establish a project war room, with a full-time dedicated launch manager and a robust governance structure for quick decision making. The war room thus becomes the nexus of project governance, featuring daily launch check-in meetings for the escalation of problems and issues and rapid problem solving. All launch teams should meet at least once a week and engage in steering discussions to manage issues that extend beyond day-to-day problem solving. Another use for the war room involves holding progress reviews every two to three weeks where senior executives (above the plant-manager level) participate.

Another priority centers on establishing a standing decision-control board with a clearly defined escalation ladder, ensuring strong progress tracking and KPI-measurement standards. The system should feature standardized change requests that address war-room operations themselves as well as first- and second-level decision-board involvement as needed. For example, first-level decision-board participation might focus on timing, vendor shifts, or content changes, while second-level involvement would include top management and could concern highly risky or far-reaching changes.

To establish world-class software-development capabilities, OEMs need to take proactive steps to solve software issues and create a development engine with a holistic software-transformation program. The goal is to fix the basics and develop solid processes, methodologies, and tools that allow engineers and managers to focus on the right priorities to set themselves up for success, independent of any potentially problematic launch project at hand.

Ondrej Burkacky is a partner in McKinsey's Munich office, where **Georg Doll** is a senior expert and **Dominik Hepp** is an associate partner; **Rupert Stuetzle** is a partner in the Berlin office.

Designed by Global Editorial Services

Flying-cab drivers wanted

Air taxis are coming. Until they can fly autonomously, this nascent industry will need many pilots.

July 2020
by Uri Pelli and Robin Riedel

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Developing an attractive value proposition for prospective pilots

To ensure an ample supply of pilots, operators must offer them an attractive career path. Otherwise, high pilot churn might break their business case. The career path might, in some cases, extend beyond operating UAM vehicles for a few years. The options could include serving in nonpilot roles within the operators' scope (for example, as remote operators), reskilling for a future outside aviation, or a transition to piloting commercial jets. The latter option would require flow-through agreements with airlines and financing for type-rating training. Operators could also subsidize the cost of basic flight training to improve the economics of a UAM pilot's short career and make it easier to enter.

Managing the pilot workforce

As we have noted, none of the aspiring UAM operators have strong, rigorous employee-management functions to recruit, retain, and direct employees. They will have to develop these capabilities when they scale up. They will also have to build the capabilities specific to managing pilots, such as those required to optimize schedules, ensure regulatory compliance, create an effective safety culture, and manage organized-labor contracts.

Leveraging pilots to provide an excellent experience and increase UAM's public acceptance

Although the need for pilots will increase the costs and complexity of the UAM business, it may improve customers' experience of the ride, as well as perceptions of its safety. This, in turn, will influence the willingness of potential customers to embrace an exotic new mode of transport.

Operators should design their businesses with pilots in mind and use them to improve the customer experience. A pilot, for example, could not only instill confidence among passengers but also greet them and help them load and unload luggage. As we have already noted, only experience will show which protocols for customer–pilot interactions would create the safest, most comfortable environment.

In any case, pilots on board will gradually promote public acceptance of UAM itself. Our research shows that while most people are neutral or positive about the basic idea, they prefer flying in piloted vehicles, and the very notion of a remotely piloted one will deter some potential customers, at least for now. As the need for human controls progressively declines, the market will gradually come to accept full autonomy.

While UAM's long-term future will be autonomous, the industry must initially recruit, train, certify, and manage tens of thousands of pilots. This will likely only be the case for a few years—a problem in its own right, since pilots might not recoup their training investment, including forgone income, during their careers. Stakeholders across the spectrum—manufacturers, operators, flight schools, regulators, and employment agencies—must collaborate to tackle the significant challenges the piloted ramp-up period is certain to pose. They do not have a lot of time to prevent the supply of pilots from becoming the bottleneck that stalls this new industry's development.

Uri Pelli is a consultant in McKinsey's Philadelphia office and **Robin Riedel** is a partner in the San Francisco office.

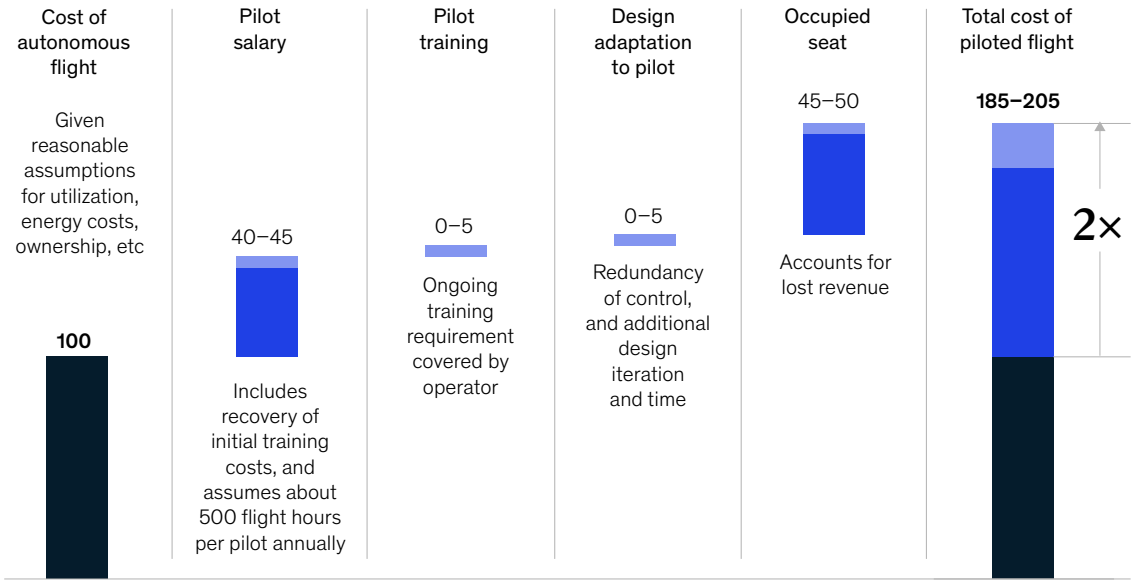
The authors would like to thank Alex Dichter, Guenter Fuchs, and Tore Johnston for their contributions to this article.

Designed by Global Editorial Services

Exhibit 1

The cost per passenger-seat-kilometer of a piloted urban-air-mobility flight could be up to twice the cost of an autonomous one.

Piloted urban air mobility (UAM), cost per passenger-seat-kilometer,[1] %



[1] Constant 2019 US dollars, not adjusted for inflation.

Source: McKinsey analysis

The pilot-sourcing challenge

Finding, training, and retaining enough pilots will be another big challenge. Before COVID-19 brought global aviation to nearly a standstill, operators of smaller aircraft were already having difficulty finding qualified pilots. Projections from before the crisis suggest that already-tight supply of commercial pilots would become even tighter in the future: at that time, current commercial operations were expected to require 320,000 newly trained aviators over the next ten years.[3] The COVID-19 crisis will defer the need for these pilots by a few years and potentially even lower the number required if commercial aviation does not return to its original trajectory. That said, there will still be a need for most of those new pilots toward the end of the decade. Pilots for UAM would come on top of that.

Before the pandemic, several promising and well-funded players announced that they were aiming to start UAM operation by 2023. Of course, the COVID-19 crisis might slow a few players down and shift the start dates by a year or two. But our modeling, based on announced launch dates and expected delays, success rates, production ramp ups, and market constraints, suggests the industry could require about 60,000 pilots by 2028, roughly 17 percent of the total number of commercial pilots in 2018 (Exhibit 2).

Some efforts to reduce the requirements for UAM pilots,[4] and consequently the training burden, are now under way. Approved programs seem many years distant, however. Until then, prospective UAM pilots will have to take today's training

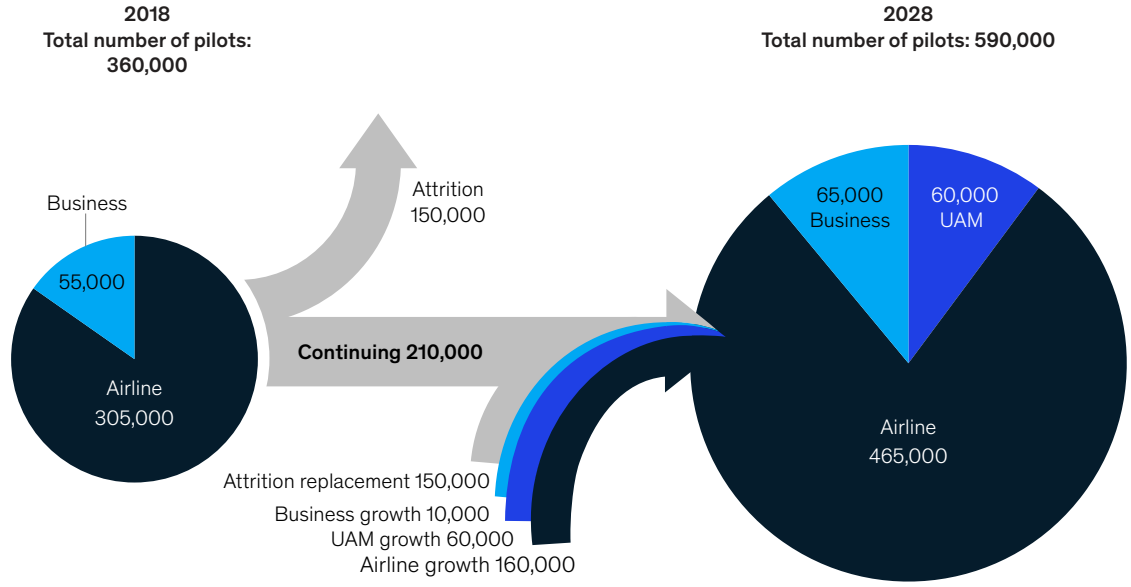
[3] "Airline and business jet pilot demand outlook: 10-year view, 2018 update," CAE, cae.com.

[4] For example, through the concept of Simplified Vehicle Operations (SVO), now being explored by, among others, the US National Aeronautics and Space Administration (NASA), the US Federal Aviation Authority (FAA), and the General Aviation Manufacturers Association (GAMA).

Exhibit 2

Urban air mobility (UAM) will accelerate demand for pilots.

Number of pilots required to fulfill urban-air-mobility (UAM) need in next decade



Note: Numbers are rounded.

Source: McKinsey Flight Crew Model, CAE Airline and Business Jet Pilot Demand Outlook, 10-year view, 2018 Update

programs. Given current training costs, it will take about $4 billion to $6 billion to train 60,000 new UAM pilots. If these aspiring aviators, like the majority today, pay for the training themselves, financial institutions must step in to overcome the tight supply of financing.

Another important challenge will involve creating a value proposition that will encourage people to embrace careers as UAM pilots despite the expense of basic flight training, the 12- to 24-month training period, and—most critically—an uncertain future. The UAM industry is quite vocal about the need to automate, potentially limiting the career of an UAM pilot to a few years. The net present value of a five-year UAM career could be quite low or even negative, given the upfront training cost and the opportunity cost of training time without income, even if compensation levels were in line with current early career pilots (around $40,000 to $60,000 per year). Further, UAM piloting skills and experience may not be transferrable either within or beyond the aviation industry. Many people might therefore believe it would be better to pursue other professions.

Most aspiring UAM operators now focus on technology, employ few if any pilots, and lack experience managing a large operational workforce—whether employed or contracted. All these things will also interfere with sourcing pilots.

The customer-experience challenge

A pilot's presence in a small capsule without a separate flight deck will surely affect the customer's experience of the ride and perceptions of its safety—potentially both positively and negatively—much as experiences with taxi or rideshare drivers do today. In turn, the pilot's presence will influence the willingness of consumers to embrace a new mode of transport. No one quite knows which protocols for customer–pilot interactions will create the safest and most comfortable environment. Will pilots be allowed or even encouraged to converse with passengers? Should they help customers who

feel airsick? How will they balance these tasks with safely operating the aircraft? And what kind of behavior by pilots will give passengers confidence in the safety of the flight? Operators will have to find answers to these questions.

The aircraft-design challenge

A pilot's presence further has implications for the design of UAM vehicles. In addition to the pilot's seat, it will be necessary to design controls and interfaces between the pilot and the aircraft. Industry players will need capabilities (for instance, in human factors) that will be superfluous on autonomous vehicles, and the transition from piloted to autonomous vehicles will require significant redesign of the vehicles. The point is not that piloted vehicles will be harder to design or more complex than autonomous ones but rather that they will be quite different. After spending some years designing and producing one kind of air taxi, their manufacturers will have to switch to designing and producing another.

Piloting the transition to autonomy: Four key initiatives

To address the challenge of recruiting, training, and certifying UAM pilots during the early years of UAM, the industry should pursue four key initiatives. All will require collaboration across a range of stakeholders, including vehicle manufacturers, technology players, operators, regulators, and flight schools.

Streamlining the training and certification of pilots

The industry and its regulators must develop a new kind of certification for UAM pilots because the current standard simply does not make economic sense for them or the industry. Certification and training requirements for today's commercial pilots are complex, lengthy, and expensive—an investment, in both money and time, that UAM pilots might not recoup before automation takes over. Therefore, it is essential to redesign the training—without compromising safety, of course. Such new programs would not only streamline training but also increase the pipeline by opening the business to people who lack traditional credentials or want new kinds of jobs late in their careers.

One important area that has to change is the curriculum. For example, commercial pilots study such topics as high-altitude aerodynamics and the technical details of high-bypass jet engines, neither of which will be relevant for UAM. The new industry's pilot-training programs should also expand the scope of digital instruction, both for ground school and practical flying lessons. Relatively low-cost simulators, for instance, could replace a significant portion of the time currently needed for flight training in real aircraft, or artificial intelligence algorithms could help adapt training to the needs of individual students in real time—for instance, by identifying areas where they require remedial training.

To ensure an ample supply of pilots, operators must offer them an attractive career path. Otherwise, high pilot churn might break their business case.

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Leveraging pilots to provide an excellent experience and increase UAM's public acceptance

Although the need for pilots will increase the costs and complexity of the UAM business, it may improve customers' experience of the ride, as well as perceptions of its safety. This, in turn, will influence the willingness of potential customers to embrace an exotic new mode of transport.

Operators should design their businesses with pilots in mind and use them to improve the customer experience. A pilot, for example, could not only instill confidence among passengers but also greet them and help them load and unload luggage. As we have already noted, only experience will show which protocols for customer–pilot interactions would create the safest, most comfortable environment.

In any case, pilots on board will gradually promote public acceptance of UAM itself. Our research shows that while most people are neutral or positive about the basic idea, they prefer flying in piloted vehicles, and the very notion of a remotely piloted one will deter some potential customers, at least for now. As the need for human controls progressively declines, the market will gradually come to accept full autonomy.

While UAM's long-term future will be autonomous, the industry must initially recruit, train, certify, and manage tens of thousands of pilots. This will likely only be the case for a few years—a problem in its own right, since pilots might not recoup their training investment, including forgone income, during their careers. Stakeholders across the spectrum—manufacturers, operators, flight schools, regulators, and employment agencies—must collaborate to tackle the significant challenges the piloted ramp-up period is certain to pose. They do not have a lot of time to prevent the supply of pilots from becoming the bottleneck that stalls this new industry's development.

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To take off, flying vehicles first need places to land

The buzz about vehicles flying above hides the infrastructure challenge below.

August 2020

by Tore Johnston, Robin Riedel, and Shivika Sahdev

The dream of using new technologies to rise above the ever-increasing urban-road congestion has gained significant momentum. With more than 250 businesses planning to build, operate, or manufacture urban-air-mobility (UAM) vehicles, all at different stages of development, a growing assortment of industry players is working across the value chain to make this dream a reality. Enabled by vertical-takeoff and -landing (VTOL) systems, electric propulsion, and advanced flight-control capabilities, these vehicles could eventually reach price points rivaling today's terrestrial taxi services.

The resulting flying vehicles will be energy efficient, quiet, environmentally friendly, and eventually pilotless.[1] Although some may question the projected costs involved, their concerns might be misplaced. Adding new transportation capacity in most cities is extremely expensive, especially if it involves tunneling for subways or bypasses. The cost of building a subway in a city can exceed $500 million per mile, for instance.[2] UAM may thus represent a more cost-effective method, in some cases.

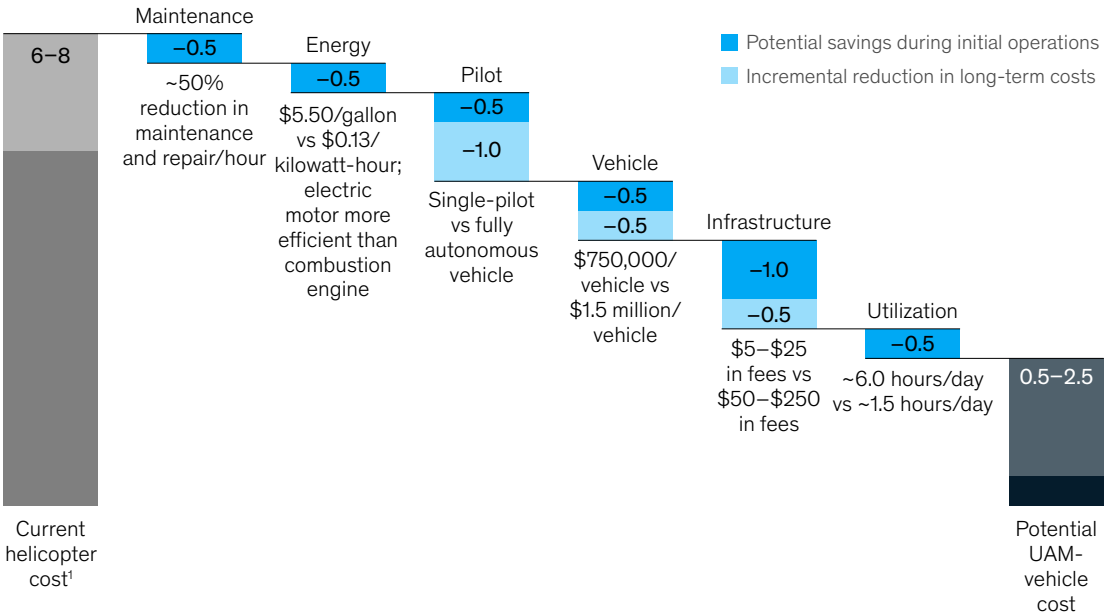
For UAM to be truly successful, trip costs must fall around 80 percent from current helicopter levels for UAM to compete with ground travel (Exhibit 1). In addition to physical infrastructure—places that vehicles take off and land—success will require a variety of infrastructure to support unmanned air-traffic control, aircraft charging and/or refueling and connectivity.

Although the coronavirus pandemic will inevitably shift market dynamics and influence the adoption rate of UAM, the sector still offers many opportunities for innovators. This article explores how physical infrastructure for UAM could evolve and help shape the market. Our discussion focuses on intracity and metropolitan UAM travel with a distance of under 50 miles. While many other use cases exist for longer trips, they have different dynamics, economics, and infrastructure needs.

Exhibit 1

Operating costs could evolve for urban-air-mobility vehicles.

Potential evolution in operating cost per seat-mile for urban-air-mobility (UAM) vehicles, $



[1]Current costs vary depending on various factors, including number of passengers and helicopter type.

[1] Uri Pelli and Robin Riedel, "Flying-cab drivers wanted," June 20, 2020, mckinsey.com.
[2] Alon Levy, "Why it's so expensive to build urban rail in the US," CityLab, January 6, 2018, citylab.com.

Physical infrastructure provides industry lift

To offer sustainable service, flying vehicles need places to take off, land, receive maintenance, charge their batteries and/or refuel their tanks, and park. Complicating the picture, traffic flows are typically unevenly distributed and highly directional. Mornings and evenings see high demand for travel, while demand is low in the middle of the day and nights. In Seattle, for instance, most travel occurs between 7:00 a.m. and 9:00 a.m. (Exhibit 2). Consequently, infrastructure must support both peak flight needs and off-peak parking needs. That creates a dilemma: infrastructure networks will be larger than needed to support "average" utilization, or else operators must spend money to shuttle empty vehicles between parking and active sites.

The physical infrastructure will be an important determinant for the size of the addressable market, since the only trips possible are between VTOL ports. If only a few ports are available, flying-vehicle transport could follow a pattern similar to that seen in today's helicopter market, where the number of potential destinations is limited. For instance, helicopter trips in cities such as London and New York can only occur between major airports and select locations in city centers—the only locations with available ports. If leaders want to scale the UAM market and not face the limits seen with today's helicopter transport, they must establish many more ports, as well as more routes among them.

The location of the infrastructure will determine market-conversion levels. The closer a passenger is to a takeoff or landing spot, the greater the potential for time savings. If a landing spot is too far away from the origin or destination, the customer might not save enough time for a UAM trip to make sense.

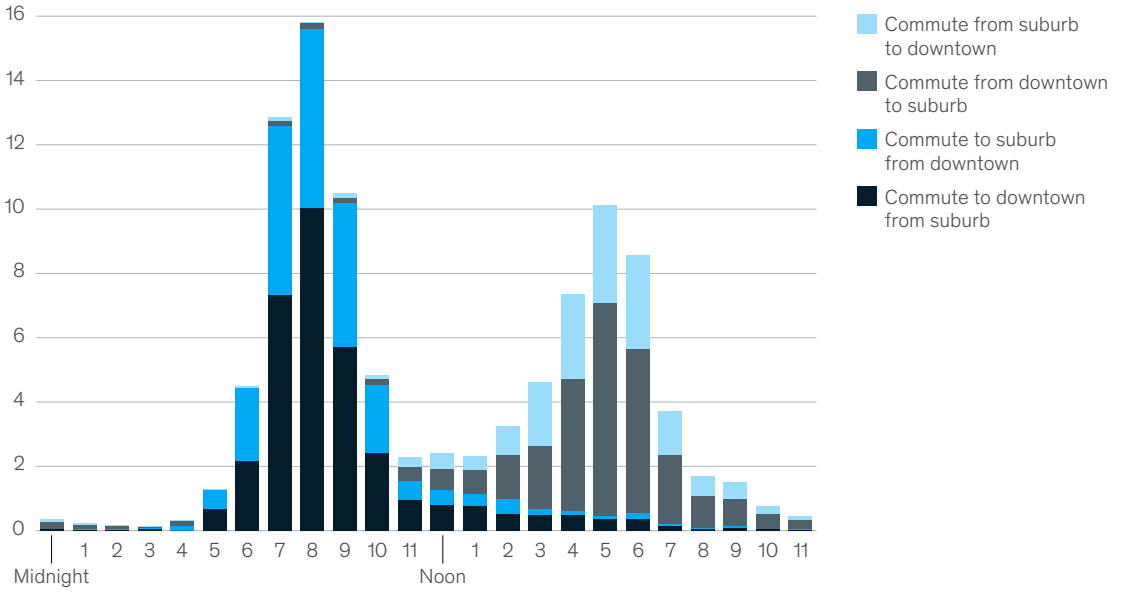
Envisioning an infrastructure network

The specific design requirements for a UAM network will vary by city. We expect that concerns about COVID-19 will increase the importance of safety during travel, and UAM stakeholders

Exhibit 2

Traffic flow varies significantly by time of day, with peaks occurring at commuting hours.

Daily traffic patterns by time of day, Puget Sound, % of total daily trips

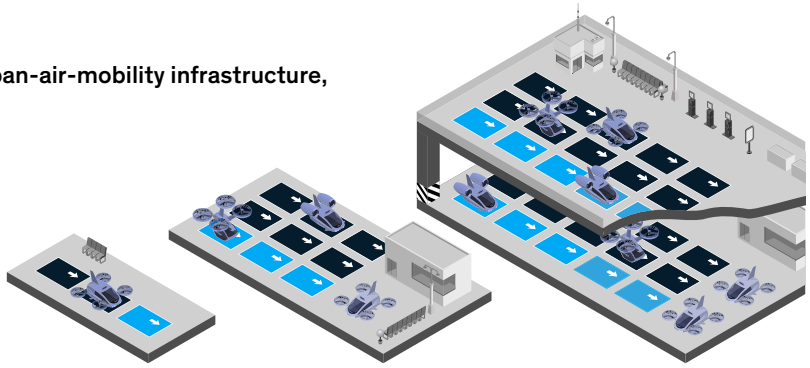


Source: "Household Travel Survey Program," Puget Sound Regional Council, Spring 2017, psrc.org

Exhibit 3

There are three potential archetypes for urban-air-mobility infrastructure.

Potential archetypes for urban-air-mobility infrastructure, illustrative



	Vertipad (new or retrofit)	Vertibase (new or retrofit)	Vertihub (new)
Dimensions	100 × 60 feet	230 × 100 feet	400 × 175 feet (2 floors)
Landing/takeoff pads	1	3	10
Parking/charging spots	2	6	20
Capital expenditures, $ million	0.2–0.4	0.5–0.8	6.0–7.0
Operating expenditures, $ million	0.6–0.9	3.0–5.0	15.0–17.0

will adapt essential infrastructure to meet those requirements. This section defines three potential UAM-infrastructure archetypes that could emerge (Exhibit 3). For each archetype, we estimate costs, and the calculations assume that the land is rented. The following are simply illustrative examples, and the section does not intend to describe all variations or provide a model of what a UAM network must include:

— *Vertihubs.* Vertihubs are the largest structures. Envisioned as stand-alone buildings constructed in central, high-traffic areas, they will have around ten active takeoff and landing areas, plus 20 additional spaces for parking or maintenance. Vertihubs could also include some level of retail and other services for passengers. We estimate they could cost $6 million to $7 million to build and $15 million to $17 million per year to operate.[3] Our operating-cost estimates do not include the cost of power for charging or refueling.[4]

— *Vertibases.* Vertibases are medium-size structures, either newly built or created by retrofitting existing structures such as parking garages and corporate-headquarters rooftops. Located in medium-traffic areas, such as suburbs, or at major work or retail locations, vertibases would have around three active takeoff and landing spaces, plus six additional spaces for parking or vehicle maintenance. We estimate they could cost $500,000 to $800,000 to build and $3 million to $5 million per year to operate.

— *Vertipads.* Vertipads represent the smallest structures and would function as the spokes in the hub-and-spoke network. As with vertibases, they could be newly built or created by retrofitting existing structures. Typically located in suburban or rural locations (up to 50 miles from the rest of the network), they would have one takeoff and landing area, plus two spots for parking or vehicle maintenance. We estimate they could cost $200,000 to $400,000 to build and $600,000 to $900,000 per year to operate.

Every city will have these three structures, but the mix will likely differ. We believe that two

[3] Depending on location and traffic levels.
[4] To allow for easier comparisons, we exclude the power cost from landing fees in subsequent analyses.

Cost remains the critical element in assessing the viability of any proposed VTOL-port strategy.

types of networks could emerge—one for large, densely populated cities, such as London, New York, and Shanghai, and a second for medium-size, less densely populated cities with both urban and suburban neighborhoods, such as Dallas and Düsseldorf.

For large, densely populated cities, there could be roughly 85 to 100 takeoff and landing pads, including the following:

- vertihubs located at one or two major airports, as well as two or three city locations around major commute corridors
- ten to 15 vertibases around commuting-origin and -destination areas
- five to ten vertipads at targeted areas of interest or for private use

Building this infrastructure network would cost approximately $35 million to $45 million,[5] with annual operating costs of around $110 million to $130 million per year.[6]

In medium-size, less densely populated cities, there would be around 38 to 65 takeoff and landing pads, including the following:

- vertihubs at one major airport and one or two city locations
- five to ten vertibases to handle workplace commutes and retail districts
- three to five vertipads near suburban commute stations

Building this infrastructure network would cost between $15 million and $20 million,[7] and annual operating costs would range from $35 million to $50 million per year.

Exhibit 4 summarizes the network structures, network costs, and annual operating costs for both types of cities.

Assessing the economics of flying-vehicle networks

Cost remains the critical element in assessing the viability of any proposed VTOL-port strategy. The following four selected insights on the economics of such infrastructure networks provide some clarity about the costs associated with a flying-taxi network.

Insight 1: The infrastructure network can break even in a small, premium market

Assume that infrastructure charges are about $150 per trip—a figure that excludes charging or refueling costs, just as inner-city heliports do today when calculating their expenses. Under these circumstances, the following scenarios would allow UAM providers to break even on fixed costs[8]:

- *Large, densely populated cities.* The network would require approximately 2,200 trips per day (one trip every 60 minutes when averaged over

[5] Capital costs include the costs of construction, chargers, and integration into the power grid. The total capital cost assumes a useful charger life of ten years before obsolescence and the need for multiple sets of chargers over a 30-year period.
[6] Operating costs include the costs of rent, land use, power, labor, and traffic management.
[7] Capital costs include the costs of construction, chargers, and integration into the power grid. The total capital cost assumes a useful charger life of ten years before obsolescence and the need for multiple sets of chargers over a 30-year period.
[8] Fixed costs include those for rent, labor, air-traffic control, and technology.

Exhibit 4

Infrastructure, network costs, and annual operating costs will largely depend on city size and population density.

Vertihub-centered-network specifications and infrastructure cost, illustrative

Large, dense, high-income urban city (eg, London, Mumbai, New York City, Shanghai, Tokyo)			**Medium-size, less dense, medium-income, urban/suburban city** (eg, Atlanta, Dallas, Denver, Düsseldorf)
Outposts, areas of interest, and private use	5–10	**Vertipads**	3–5 — Major suburban commuting stations, private use for high-net-worth individuals, and wealthy suburbs
Near concentrations of high origin and destination points	10–15	**Vertibases**	5–10 — Major corporate headquarters, major retail districts, and major commuting stations
Major airports, city centers, and major commute corridors	5	**Vertihubs**	2–3 — Main airports, downtown areas, and major work districts
	85–100	**Total takeoff and landing pads**	38–65
	35–45	**Network cost, total capital expenditures,** $ million	15–20
	Other[1] 5–10; Depreciation[3] 5–10; 55–60 Rent[2]; 45–50 Labor[4]; 110–130	**Annual operating cost,** $ million	Depreciation[3] 2–3; Other[1] 3–7; 15–20 Labor[4]; 15–20 Rent[2]; 35–50

[1]Connectivity costs and regulatory fees. [2]Cost per square foot multiplied by structure dimensions. [3]30-year useful life for buildings/land. [4]Security, customer service, maintenance, and management.

24 hours). During peak travel times, this would increase to one trip every 20 minutes.

— *Medium-size, less dense cities.* The network would require 750 trips per day (one every 100 minutes when averaged over 24 hours). During peak travel times, this would increase to one trip per pad every 30 minutes.

At this price level, the per-passenger charges would be in the $50 to $75 range, depending on the number of passengers per trip. While this is expensive, the charges are similar to those for other luxury-transport options, such as black-car and helicopter travel. Essentially, UAM in this type of small, premium market would work.

Insight 2: To achieve very low trip costs, the network needs to accommodate very rapid turnaround times

To get to per-passenger charges of $25 per trip—in line with mass-market travel today—the network must generate 10,000 trips per day in a large, dense, high-income city and approximately 3,500 trips per day in a medium-size, less dense city. These trip counts translate to more than one trip every five minutes per landing pad across the network, accounting for peak travel needs. This represents a significant challenge, given the logistics of flight. Landing, deplaning, boarding, transferring baggage, charging batteries or refueling tanks, and preparing for takeoff are likely to take more than five minutes. The increasing importance of ensuring safety in a post-COVID-19 world could also increase the time between flights because of the need for intensive aircraft cleaning and appropriate physical distancing among passengers. It will likely be a challenge for every port to complete all required tasks reliably and consistently in the short time frame available.

Insight 3: Achieving a return on invested capital, excluding charging and refueling costs, could be feasible

While networks can cover operating costs through landing fees, UAM infrastructure will not be cheap to build. Construction at the sites to build the ports, tooling for maintenance activities, and other smaller expenses,[9] such as lighting and emergency preparedness, could cost between $15 million and $45 million. It also would take time to ramp up trip volume (Exhibit 5). Consider the following scenario: infrastructure gets built, and the desired number of trips ramps up over five years, which is likely a realistic time frame. In this case, the infrastructure owners would have to charge a 15 to 20 percent margin on landing fees to achieve a reasonable return on their capital investment. If passenger traffic continues to rise, network operations will increase in scale, resulting in further cost reductions and a larger addressable customer base.

Exhibit 5

Return on investment for urban-air-mobility infrastructure is more difficult to achieve when including costs for charging infrastructure, electricity, and refueling.

Return on infrastructure investment, based on inclusion and exclusion of charging-infrastructure and electricity/refueling costs,[1] %

Excluded

Margin on break-even landing fees,[2] % \ Years to ramp-up to steady-state network utilization	1	2	3	4	5
5	–12.6	–24.3	–35.5	–46.1	–56.2
10	74.7	51.3	29.0	7.8	–12.4
15	162.1	127.0	93.5	61.7	31.3
20	249.4	202.6	158.0	115.5	75.1
25	336.8	278.3	222.5	169.4	118.9
30	424.1	353.9	287.0	223.3	162.7
35	511.5	429.6	351.5	277.2	206.4
40	598.9	505.2	416.0	331.1	250.2
45	686.2	580.9	480.5	385.0	294.0
50	773.6	656.5	545.0	438.9	337.8
55	860.9	732.2	609.5	492.8	381.5
60	948.3	807.8	674.1	546.6	425.3
65	1,035.6	883.5	738.6	600.5	469.1

Included

Margin on break-even landing fees (including energy),[2] % \ Years to ramp-up to steady-state network utilization	1	2	3	4	5
5	–80.2	–82.8	–85.4	–87.8	–90.1
10	–60.3	–65.6	–70.7	–75.5	–80.1
15	–40.5	–48.5	–56.1	–63.3	–70.2
20	–20.6	–31.3	–41.4	–51.0	–60.2
25	–0.8	–14.1	–26.8	–38.8	–50.3
30	19.0	3.1	–12.1	–26.6	–40.3
35	38.9	20.3	2.5	–14.3	–30.4
40	58.7	37.4	17.2	–2.1	–20.5
45	78.6	54.6	31.8	10.1	–10.5
50	98.4	71.8	46.5	22.4	–0.6
55	118.2	89.0	61.1	34.6	9.4
60	138.1	106.2	75.8	46.9	19.3
65	157.9	123.4	90.4	59.1	29.2

[1]Medium-size, less dense city.
[2]Landing fees cover expected operating costs, such as labor and rent; for the case on the right, they also cover energy costs for charging/refueling.

[9] Smaller costs include those for lighting, flags, fire suppression, and emergency-response kits.

Insight 4: The cost of charging or refueling, both initially and ongoing, is significant and will affect the business case

The UAM industry is taking various approaches to vehicle propulsion, including electric batteries (necessitating fast charging or battery swapping), hybrid gas and electric, and hydrogen. The infrastructure required for superfast charging of UAM vehicles does not yet exist. To create it, networks would need to install the necessary physical hardware and then pay utilities for electricity drawn at very fast rates. In such cases, the cost of the charging infrastructure could be between 65 and 75 percent of the total initial capital expense, unlike the cost of fueling infrastructure today. Similarly, the cost of the electricity could be 30 to 35 percent of the estimated annual operating expenses.

What will it take to make this work?

Although infrastructure networks face significant economic and operational challenges, they can evolve to support the UAM market if the following enablers are present:

— *Ancillary sources of revenues*. Infrastructure operators could leverage ancillary sources of revenue beyond landing fees. Airport operators follow this strategy today, obtaining about half of their revenue from nonairline-traffic sources, such as retail, personal-services, and integration fees.[10]

— *Private and corporate investments.* Private companies or individuals could invest in ports at large corporate headquarters or personal estates to help support the initial market.

— *Public-sector subsidies.* Cities and states could consider subsidizing network construction to enhance public welfare. In addition to reducing commute times, these efforts would bolster their public image and improve tourism. Cities and states that have undertaken other transport-infrastructure initiatives, such as the Shanghai magnetic rail, have often seen gains in these areas.

— *Small-scale and retrofit projects first.* Rather than starting with large and expensive vertihubs, which must be newly built, stakeholders should initially focus on encouraging trips that use existing helipads or undertaking small-scale projects to retrofit pads and bases. They should also concentrate on routes that are likely to draw the most traffic and passengers with high willingness to pay. As the market takes root and demand starts to grow, stakeholders can invest in the larger new builds.

— *Innovative power solutions.* While this article focuses on the physical space required for the UAM market to take flight, the power/fuel infrastructure required to enable rapid battery swapping, hydrogen refueling, or extremely fast high-power charging—for instance, in a two- to three-minute time frame—is also critical. Infrastructure operators should work with utilities and/or fuel providers to streamline this part of the solution.

— *Modular infrastructure solutions.* In addition to using existing helipads, the early market will benefit from "infrastructure in a box" solutions that can quickly convert the top of a parking garage or building into a functional vertipad or vertihub through a lease, subscription, or revenue-share model.

[10] Airports Council International, aci.aero.

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